SECOND SERIES OCTOBER 1942 VOL. 18, NO. 10

BULLETIN OF THE NEW YORK ACADEMY OF MEDICINE

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Published monthly by THE NEW YORK ACADEMY OF MEDICINE
2 East 103 Street, New York

Entered as second-class matter, February 3, 1928, at the Post Office at New York, N. Y., under the Act of August 24, 1912. Subscription, United States, Canada and Cuba, $3.00; all other countries, $4.00 a year. Single copies, 50c.

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BULLETIN OF
THE NEW YORK ACADEMY
OF MEDICINE

OCTOBER, 1942

ADJUSTMENTS OF NERVE ENDINGS*

CARL CASKEY SPEIDEL

Professor of Anatomy, University of Virginia

Harvey Lecture, January 16, 1941

THE nerve cell is the structural unit which underlies nervous activity. Nerve cells function in groups and in chains, the separate cells being linked with one another at synapses through their nerve fiber endings. Nerve endings are also the structures which receive impulses from the sensory apparatus and deliver impulses to the motor apparatus. It is obvious, therefore, that changes and adjustments in nerve endings may be of profound importance.

In his classic work Cajal[1] has presented a very complete picture of microscopic changes in nerve cells and endings as these undergo degeneration and regeneration in various parts of the peripheral and central nervous system. His observations were made on fixed and stained material. Such a technique did not permit observations of the sequence of changes in the same individual endings. Nevertheless, Cajal had no difficulty in recognizing the normal resting nerve ending, the ending with a growth cone at the tip, and the retracting ending with a retrac-

* This work has been aided by grants from the Grants-in-Aid Committee of the National Research Council, the Committee on Research of the American Philosophical Society (from the Penrose Fund), and the Committee on Scientific Research of the American Medical Association.

tion club at the tip. He also recognized that nervous autotomy sometimes occurred.

After his invention of the tissue culture method Harrison[2] made the first important direct observations on the living young nerve fibers as these grew out from explanted nerve cells. He described in detail the activities of the growth cones and the part they play in the spinning of new nerve fibers. Many other investigators have since used the tissue culture method in studying nerve cells explanted from various parts of the nervous system.

An interesting and significant point is that so far in tissue culture the myelin sheath has not been differentiated. This is true even in cultures in which nerve cells and neurilemma cells are kept in intimate association with one another. The nerve endings that are present in tissue cultures, therefore, can hardly be regarded as mature endings of the type that in the living animal represent the terminations of myelinated fibers.

Some years ago I found that it was possible to watch individual nerve fibers for prolonged periods in living frog tadpoles. A simple technique was used involving microscopic examination of the animal in a special upright chamber, the animal being temporarily immobilized with a weak anesthetic. With care the entire history of the same nerve fiber could be obtained for periods of several days or weeks, the animal being kept in good condition throughout the observations. Moreover, it was found possible to take satisfactory ciné-photomicrographs revealing minute details of the changes in nerve fibers and their endings. Especially valuable were pictures of the "fast motion" type which vividly revealed relatively slow changes.

The growth of individual nerve sprouts, the movements of neurilemma cells, and the process of myelin sheath formation were first studied.[3,a,b,c] This was followed by experimental studies of the phenomena accompanying nerve irritation and recovery, injury and repair,[3,d] and by studies of the effects on nerve fibers of alcoholic intoxication[3,e] and metrazol treatment.[3,f] Recent work, not yet published, has dealt with the effects on nerve fibers and their endings of electric shocks and of insulin treatments. The increasing use of shock therapy in the treatment of human mental disorders makes this field of investigation of timely interest. Other recent work, also as yet unpublished, has dealt with the changes in nerve endings during periods of normal rapid growth in size of the animal, during alternating periods of starvation

and good nutrition, during alternating periods of exposure to strong and weak anesthetics, and during temperature variations.

In this lecture I propose to give an account of the fundamental structural changes in nerve endings that are discernible under both normal and experimental conditions. This account includes changes associated with growth, regeneration, starvation, treatments with chloretone, alcohol, metrazol, insulin, electricity, hypertonic salt solutions, X-rays, and temperature variations. This account also includes adjustments of nerve endings associated with local tissue changes, such as occur during the progress of myelination, during tissue regulation after wound infliction, during the establishment of collateral innervation after experimental denervation of nearby territory, and during various local cellular movements.

Observations and Experiments

A typical mature tree of endings of a myelinated fiber is shown in the accompanying illustration (Fig. 1).* This sketch gives the appearance not only of the ordinary endings in the resting stage but also of those in stages of growth, retraction, irritation, and degeneration.

Extension and Retraction of Nerve Endings During Early Growth and Regeneration

The phenomena of marked extension and retraction are most readily to be seen at the tips of young or rapidly regenerating nerve fibers. In the living frog tadpole at an early stage of development cutaneous nerve fibers may be watched as they grow out toward the skin (Fig. 2). Typical mobile growth cones are present at the tips. These advance in somewhat sporadic fashion. The rate of progression, therefore, is subject to great variation. About 40 micra per hour represents rather rapid growth. At the tips of the proximal stumps of regenerating nerve fibers growth cones also develop and move out in similar fashion.

Second and later growth cones of other nerve fibers follow the line laid down by the first and a small nerve is thus formed. The fibers are naked at first. Soon, however, neurilemma cells move out along the nerve, multiply, and play an important role in the formation of both myelin sheath and neurilemma. Characteristic terminal arborizations, such as are shown in Fig. 1, ultimately develop on myelinated fibers,

* All figures except the last (Fig. 18) represent nerve fibers in the tail of the frog tadpole.

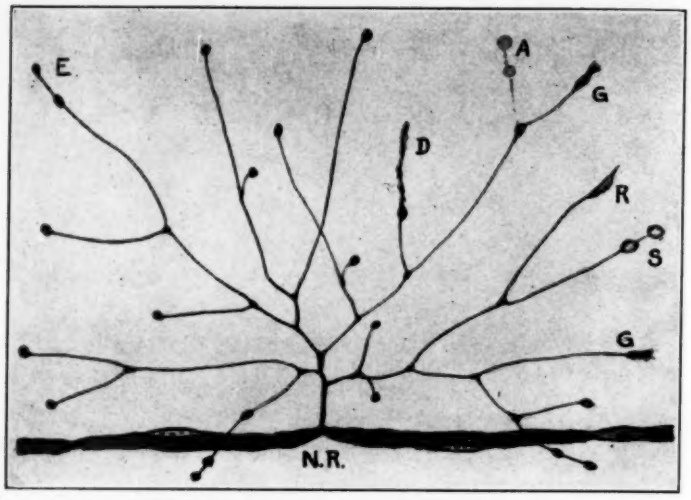

Fig. 1—Diagram showing a cluster of cutaneous nerve endings. At a node of Ranvier (N.R.) a collateral branch is given off which subdivides as shown. At the tips of most of the branches are typical resting endings (E). Two endings are characterized by growth cones (G), one by a retraction club (R), and one by a markedly swollen condition (S). A short length of one branch is in degeneration (D) and another in process of autotomy (A). This illustration of frog tadpole nerve endings peripherally located affords an interesting comparison with that of cat nerve endings centrally located (cf. Fig. 18).

not only at the end of the most distal myelin segment, but also at collateral side branches which appear at some of the nodes of Ranvier. At the tip of each branch of a terminal arborization is a small spherical or ovoid end bulb (bouton). Any one of these, however, may become transformed into a growth cone and advance, or into a retraction club and retreat.

Rapidly growing nerve endings under certain conditions may cease their advance and then undergo rapid retraction. This sometimes takes place spontaneously. It may also be induced readily by various experimental procedures. Among the methods which I have used to bring about retraction of growth cones are the following: treatment with alcohol, chloretone, metrazol, insulin, electricity, heat, hypertonic sodium chloride solution, starvation, and wound infliction by cutting or bruising nearby tissues with resulting general tissue adjustments.

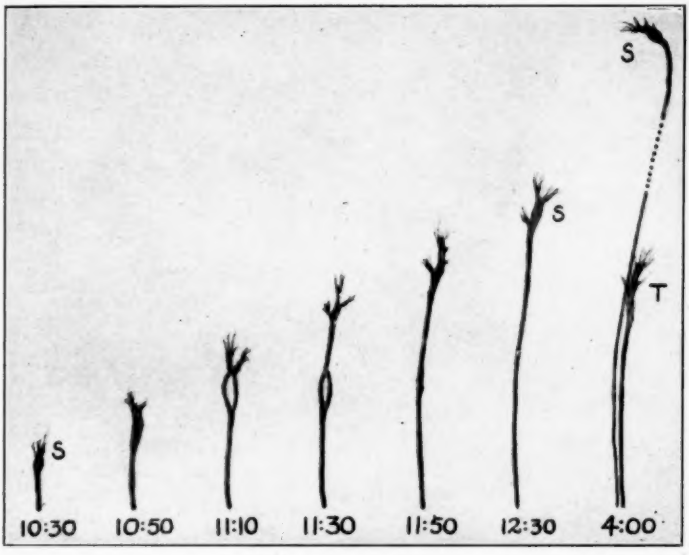

Fig. 2—Normal rapidly growing nerve endings in a young tadpole shortly after hatching. A pioneer growth cone (S) at the tip of a single nerve fiber advanced through the tissues of the tail fin, its progress being shown from 10:30 A.M. to 4:00 P.M. At the end of one hour it had traveled about 45 micra; at the end of two hours 85 micra; and at the end of five and one-half hours 220 micra. (The dotted line in the final sketch indicates that a part of the fiber has been omitted from the drawing.) A second growing tip (T) followed the line laid down by the first.

Retraction is initiated first by the transformation of a growth cone into a retraction club, and then by a regressive flow of neuroplasm proximally (Fig. 3). A fine pointed axial filament is often left for a time; then this is withdrawn. Sometimes a vigorous production of transient knob-like excrescences accompanies the retraction. These resemble similar excrescences that often characterize cells dividing by mitosis.

The speed of retraction varies greatly. Over a brief period the amount of retraction sometimes exceeds the rate of one micron per minute, as in the case illustrated (Fig. 3). Usually, however, the rate of retraction is not so great.

It is possible to induce conditions experimentally which alternately favor growth and retraction. The example given (Fig. 4) shows how variations in the degree of chloretone anesthesia are effective in bringing about conditions which favor alternately retraction and growth.

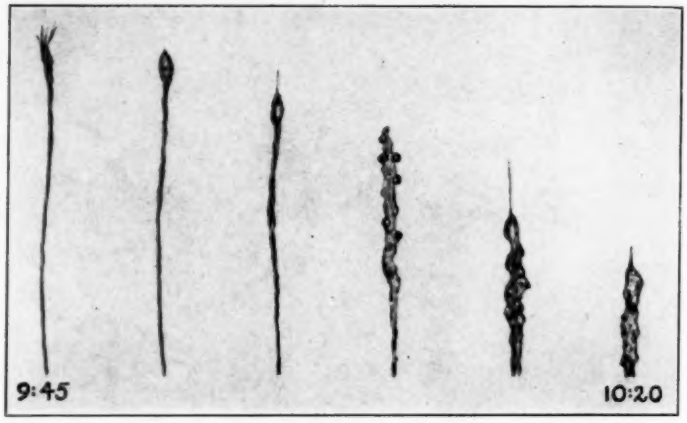

Fig. 3—Rapid retraction of the tip of a regenerating nerve fiber. An active growth cone advancing through the tissues at 9:45 A.M. became transformed into a retraction club and then vigorously retracted. At 10:20 A.M. it was in the position shown, having retracted about 45 micra.

In an earlier investigation[3,f] I have described similar instances in metrazol-treated tadpoles.

As an ending recovers and grows out again after a period of retraction, it may, or may not, follow its former course. Case histories which illustrate each of these possibilities have been presented in a previous paper which described nerve ending reactions in tadpoles subjected to alcoholic intoxication.[3,e]

Changes in the Endings of the Terminal Arborization of Myelinated Fibers During Normal Growth

In general, as a tadpole grows in size the clusters of cutaneous nerve endings of myelinated fibers also grow. Although the majority of the endings of a cluster are directed superficially toward the skin, a few may be directed deeply. Aberrant deep sprouts of this type which are of no service as cutaneous endings undergo readjustment along one of the following lines: they may advance further through the tissues and then extend superficially to establish cutaneous connections; they may retract variable distances and then change their direction of growth to reach the skin; they may suffer a variable amount of degeneration or autotomy with subsequent growth to a superficial position; or, finally,

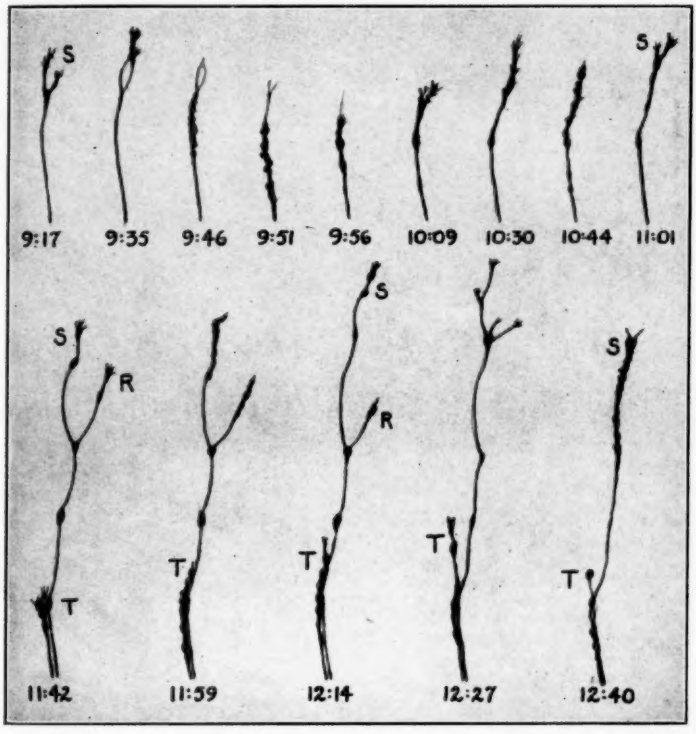

Fig. 4—Successive retraction and extension of regenerating nerve endings, correlated with treatments with strong and weak chloretone solutions. An active pioneer growth cone (S) and a second growth cone (T) were watched in a tadpole under chloretone anesthesia from 9:17 A.M. to 12:40 P.M. Strong chloretone treatments were given from 9:37 to 9:52, from 10:33 to 10:53, from 11:49 to 12:07, and from 12:29 to 12:40. At other times over the period illustrated the tadpole was immersed in either pond water or very weak chloretone solution. Typical retraction stages followed each of the four strong chloretone treatments; as at 9:46 and 9:51, at 10:44, at 11:59, and at 12:40. Typical growth stages characterized the other periods while the tadpole recovered in pond water or in weak chloretone. Before 11:42 a second growth cone (T) grew into the field illustrated, following the line of the pioneer fiber. A short branch (R) was present for about one hour, but retracted fully before 12:27.

they may be completely eliminated by either full retraction or autotomy.

I have obtained several complete case histories of the changes in entire trees of nerve endings while the frog tadpole grew markedly in size over a period of a month.* The example given here illustrates the

* Details of these have now been published in the *J. Comp. Neurol.*, 1942, *76*:57.

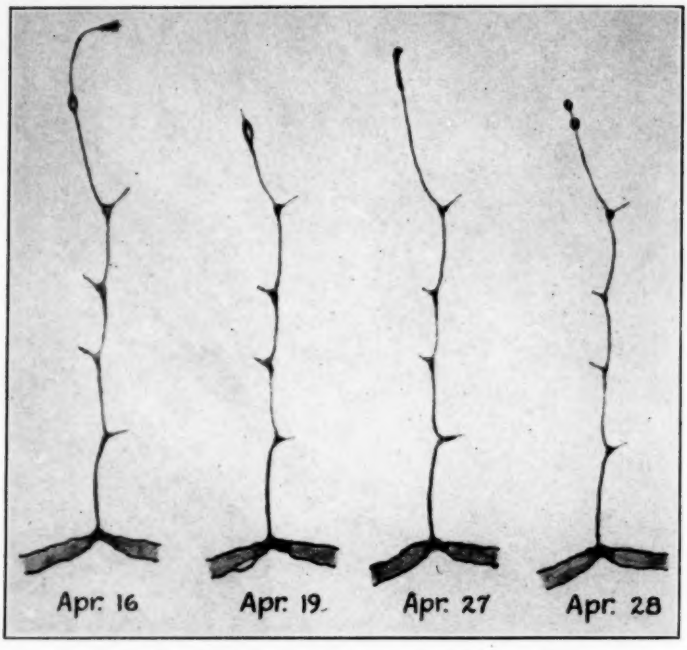

Fig. 6—Successive retraction and extension of a nerve ending correlated with successive periods of starvation and good nutrition. A motion picture record of this case was obtained. On April 16th a nerve ending with growth cone tip was observed slowly advancing. After three days of starvation definite retraction had taken place. On April 19th a typical retraction club was present at the tip. From April 20th to 27th food was made available and the ending again advanced. A second period of starvation was followed by a second retraction on April 28th.

changes of only two of the endings of a terminal arborization (Fig. 5). These are sufficient, however, to indicate that extension, retraction, branching, and elimination of branches all may take place during normal growth. They indicate further that a gradual increase in nerve ending extent is correlated with the increase in the growing terrain, and that a marked decrease in nerve ending length finally results when the tail fin undergoes reduction in size as metamorphosis starts.

Nerve endings often reflect general growth conditions. They are markedly influenced by variations in nutrition. Thus, in two tadpoles in which end arborizations were under observation for several weeks it was noted that a complete change of aquarium water and food mate-

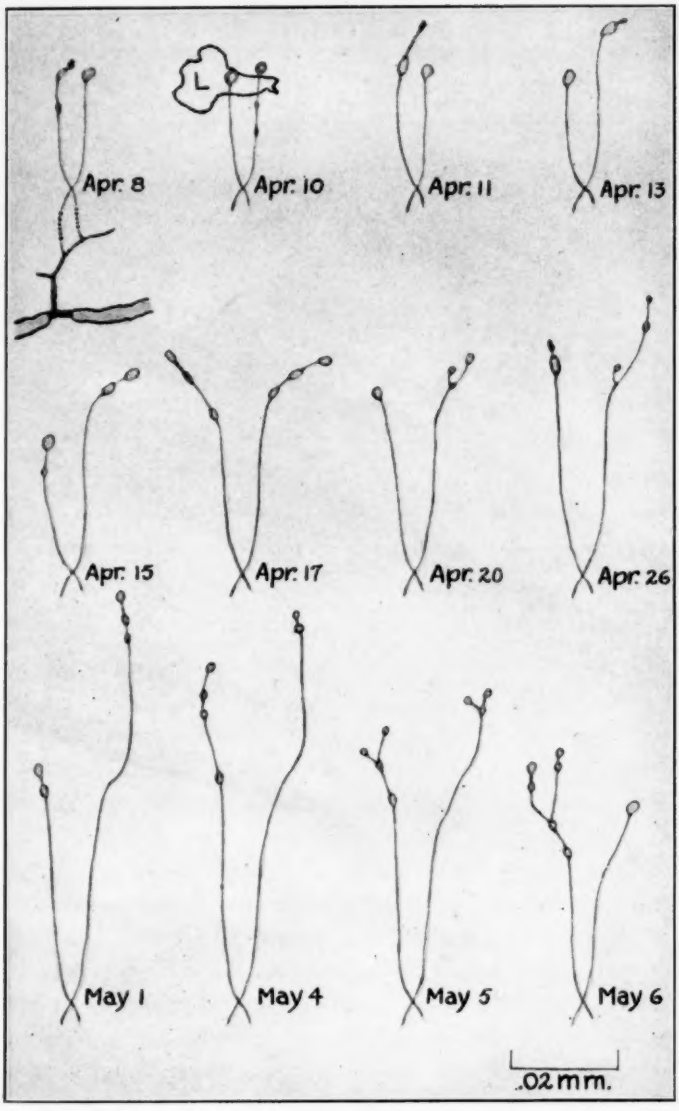

Fig. 5—Adjustments of two nerve endings over a period of four weeks during marked growth of the tadpole. The sketches are made exactly to scale from motion picture records. A distance of 0.02 mm. (20 micra) is indicated below. During the period from April 8th to May 6th, the ending exhibited extension, retraction, and branching. On April 10th a leukocyte (L) approached and pressed against the ending at the left. Extension of this ending occurred shortly afterward. The final reduction in length of the endings from May 4th to May 6th was correlated with reduction in the size of the tail fin, as the tadpole began metamorphosis. (The dotted lines in the first sketch indicate that some of the nerve fiber length has been omitted from the drawing.)

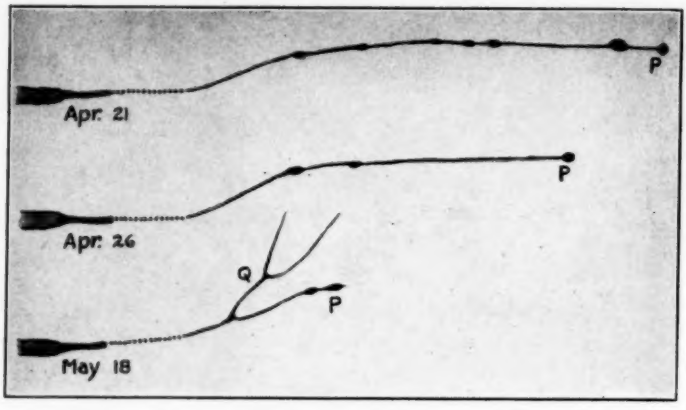

Fig. 7—Nerve ending retraction and new branch formation correlated with starvation succeeded by good nutrition. A motion picture record of this case was obtained. From April 18th to April 26th a tadpole was deprived of food; thereafter food was made available. A nerve ending (P) retracted about 18 micra during the period from April 21st to 26th. After that, in spite of the fact that food was made available, retraction continued to the extent of about 60 micra. Proximally along the retracting ending, however, a new branch (Q) grew out. (The dotted line indicates that some of the length of the fiber has been omitted from the drawing.)

rials brought about a spurt of general bodily growth within a few days. In each of these animals the nerve endings under observation exhibited, likewise, marked growth during the same period. Conversely, if food conditions are not quite favorable enough to support general bodily growth in a young tadpole, nerve endings are likely to exhibit little or no growth. Individual branches of a terminal arborization may react independently. One ending may grow while another retracts.

Terminal arborizations of regenerating fibers develop in regenerating zones about two weeks after partial tail amputation. Myelination progresses rapidly at this time. Case histories of the changes in the nerve endings of such regenerating regions are quite similar to those of normal growth, although somewhat greater variation is displayed.

Effects of Starvation on Nerve Endings

Starvation causes general changes in the tissues of the tadpole's tail. Epithelium, muscle, connective tissue, and nerve all exhibit definite irritative changes. Nerve endings may undergo swelling, retraction, autotomy, and degeneration. Examples of each of these have been observed.

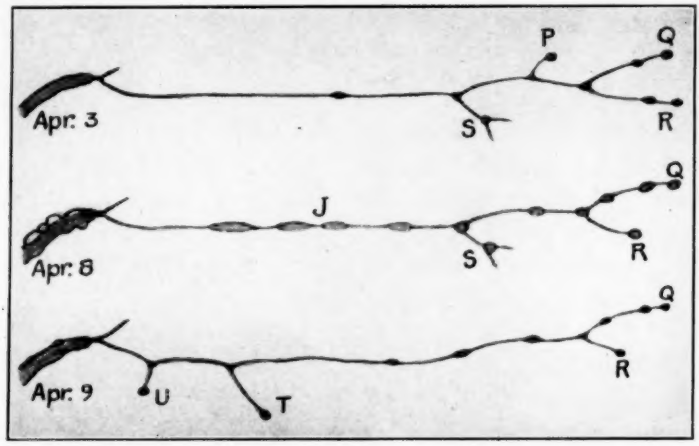

Fig. 8—Some changes in nerve endings correlated with alcoholic intoxication. Tadpole subjected to 3% alcohol for 47 minutes on April 3rd and again for 95 minutes on April 8th. Nerve ending, P, was eliminated after the first treatment. Ending, S (with its two sub-branches which are not fully shown in the drawing), was eliminated after the second treatment. Ending, R, underwent some retraction. New branches, T and U, appeared after the second treatment. Marked uneven swelling of the fiber also was visible in the region of J, on April 8th; also at Q, R, and S.

Young tadpoles are particularly responsive to alternating periods of starvation and good nutrition. Their nerve endings display regressive changes alternating with progressive changes. In the example given (Fig. 6) successive advance and retreat of a nerve ending were induced. This was correlated with the general nutritive conditions. While exact correlation was not found for all individual nerve endings in cases of this type, it was quite obvious that starvation brought about general regressive changes in both nerve fibers and their endings.

The other case cited (Fig. 7) indicates that regressive change in an ending initiated by starvation may continue, as regards that particular ending, even after good nutrition is restored. The recovery in this case was shown by the development of a new branch some distance proximally to the retracting ending.

A nerve ending in another starved tadpole formed the subject of an interesting motion picture record. As the picture was being taken, a greatly swollen end bulb underwent autotomy, after which it was ingested by a phagocytic leukocyte, while a new abortive growth cone appeared at the new tip of the nerve ending.

Some Changes in Nerve Endings Correlated with Alcoholic Intoxication

Frog tadpoles, immersed in weak solutions of alcohol for suitable periods of time, become slightly dazed. Their nerve fibers and nerve endings exhibit conspicuous changes. These changes have been described elsewhere in some detail with illustrations of many individual case histories.[3,6] Myelinated fibers exhibit vacuolation, fibrillation of the axis cylinder, swelling, progressive separation of axis cylinder and myelin sheath, globule formation, and in extreme cases complete degeneration of some myelin segments with or without degeneration of the corresponding length of axis cylinder.

The cutaneous nerve endings exhibit swelling, retraction, and degeneration with or without autotomy. Sometimes retraction is sufficient to bring about elimination of a branch. During the recovery period following alcoholic intoxication, irritated endings may exhibit reduction of swelling, extension, and the formation of new branches. Endings of the fiber illustrated (Fig. 8) exhibit swelling, retraction, elimination of some branches, and formation of other new ones. A normal end bulb is in the gel state. With increasing irritation an end bulb changes progressively from the gel state toward the sol state; with recovery it returns to the gel state.

The effects of alcohol on growing nerve sprouts during rapid regeneration are even more striking. I have taken motion pictures of growth cones as they are transformed into retraction clubs which then rapidly retreat. With restoration of normal conditions the retracting nerve tips within a short time develop new growth cones and resume their advance through the tissues. They may proceed along their former course or along a new path. Examples of each have been observed and recorded ciné-photomicrographically. Rapidly regenerating nerve tips exhibit in somewhat exaggerated fashion the same fundamental changes shown by the resting nerve endings of terminal arborizations.

The Neurilemma in Relation to the Duplication of an Original Nerve Pattern by a Regenerating Fiber

An important question in the regeneration of a nerve fiber and its endings concerns the extent to which exact duplication of an original pattern may be expected. Several case histories of experimental nerve

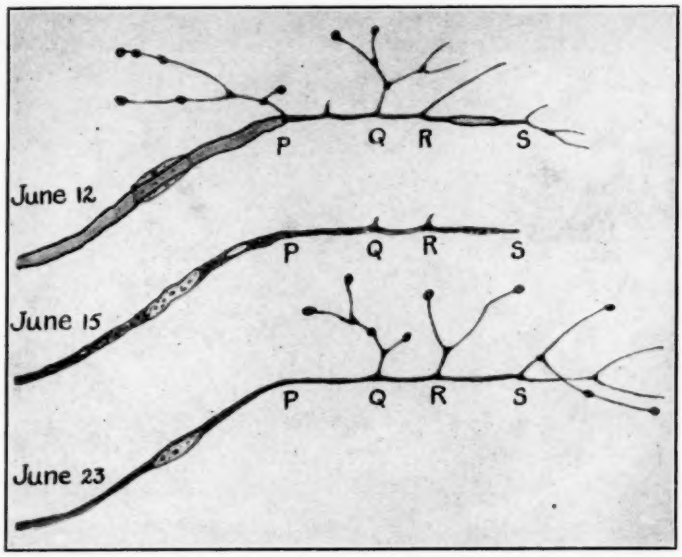

Fig. 9—The neurilemma as a directing factor during nerve regeneration in the exact duplication of an original pattern. On June 12th a nerve fiber ended as shown with branches at P, Q, R, and S. The fiber was then sectioned some distance proximally. On June 15th degenerating remnants of the fiber were still visible within the neurilemma. The neurilemma was visible as far distally as S with short funnel-like extensions at Q and R, though not at P. On June 23rd the regenerating fiber had grown back into the old neurilemma and had given rise to a set of endings at Q, R, and S. Exact duplication of the original nerve pattern corresponded only to the part enclosed by neurilemma. The pattern of branching of the fiber not ensheathed by neurilemma was unlike the original pattern. Collateral branches appeared at Q and R, but not at P, a result possibly correlated with the presence or absence of neurilemma side extensions at these points (cf. also Fig. 10).

section and of spontaneous degeneration and regeneration of fibers under observation have yielded clear-cut data on this point. The example given (Fig. 9) shows that a regenerating fiber growing within the old neurilemma tube duplicated the original pattern only as far as the neurilemma extended. Any branches that arose distally to this were naked and their pattern of branching bore no special resemblance to the original pattern.

Other case histories have given similar results. The inference is clear that the patterns of free unsheathed nerve endings which suffer degeneration are not exactly reproduced by regenerative processes. This fea-

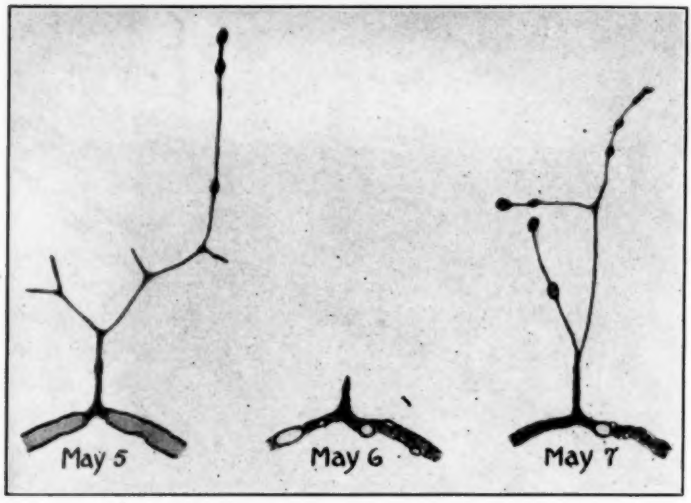

Fig. 10—Severe injury of a nerve fiber by metrazol treatment, with degeneration of a collateral branch with its cluster of endings followed by regeneration of a new collateral with a new pattern of endings. A motion picture record of this case was obtained. On May 5th a collateral of a myelinated fiber at a node of Ranvier branched as indicated. (The drawing shows the tip of only one of the branches.) Metrazol was administered in strength sufficient to induce degeneration of the entire collateral branch, as well as a short length of the main myelinated fiber. On May 6th the neurilemma sheath was present filled with degenerative debris of the fiber. On May 7th the main fiber had regenerated and given rise to a collateral at the former node of Ranvier site. Three endings developed on the collateral. The pattern of branching, however, was quite unlike that of the original pattern before the injury.

ture of nerve ending regeneration is of decided significance in connection with the question of synapse stability in the central nervous system, a problem to be discussed below in this paper.

Degeneration and Regeneration of Nerve Endings in Metrazol-treated Tadpoles

Profound alterations become visible in the tissues of metrazol-treated tadpoles. The circulation is markedly affected. It may stop temporarily in the small vessels near the edge of the tail fin. Muscle, epithelium, and nerve all exhibit structural changes.

The nerve changes are of special interest. They afford a basis for the interpretation of certain results that have been obtained in the treat-

ment of human mental disorders by injections of metrazol. In a previous paper[3,t] I have described the results of subjecting tadpoles to mild, moderate and severe treatments with metrazol. Case histories have been presented which illustrate nerve fiber recovery after various gradations of irritation and injury. One example is offered here (Fig. 10) of the degeneration of a cluster of endings after severe metrazol treatment, followed by regeneration of a new group of endings with a different pattern. In this case the metrazol treatment caused elimination of an entire terminal arborization. It also caused degeneration of several of the most distal myelin segments of the main fiber as well as some of the corresponding axis cylinder. Nevertheless, regeneration quickly ensued. A new sprout grew out from the main fiber at the place of the original collateral. Its manner of branching, however, bore no resemblance to the pattern of the original arborization. This case, like that of Fig. 9, indicates that the patterns of free unsheathed nerve endings which undergo degeneration are not exactly duplicated by regenerative processes.

Reactions of Nerve Endings in Tadpoles Subjected To Electric Shocks

One of the best means of bringing about alterations in nerve ending patterns is through the use of electric shocks of suitable strength and number. Along with metrazol and insulin treatments for certain human mental diseases, the electric shock therapy has been gaining favor. Observations of nerve ending reactions to electricity in tadpoles, therefore, are of particular interest because of their possible application to nerve ending changes at synapses in the brain of human mental patients following electric shock treatments.

I have subjected tadpoles to various degrees of electrically-induced injury. Excellent case histories have been obtained of nerve fibers and their endings as these suffer injury and then recover. The example given (Fig. 11) shows a swollen nerve fiber on the day following a fairly severe series of electric shocks. One small branch underwent degeneration. Another ending, though somewhat swollen, readily recovered and grew out into new territory.

Other case histories of electric shock injury and recovery indicate that loss of nerve substance may be much greater in extent. In extreme cases an entire collateral may suffer degeneration, as in the metrazol

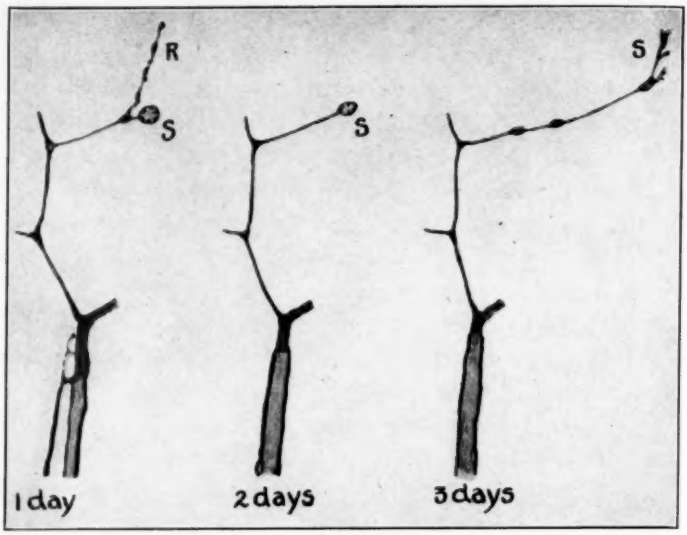

Fig. 11—Elimination of one nerve ending, and swelling and extension of another following electric shock treatments. On the day following a series of electric shocks a myelinated fiber was noted in greatly swollen condition. One ending (S) exhibited swelling. Another short branch (R) was in process of degeneration. On the next day (i.e., two days after the electric shocks) the myelin segment was almost normal; the ending (S) was less swollen; and the ending (R) was gone. On the following day S had advanced markedly and was provided with a growth cone.

case cited above (cf. Fig. 10). In one rather interesting case the electrical treatment was just strong enough to induce degeneration of several myelin segments of a fiber. The enclosed axis cylinder, however, survived although its endings suffered marked reduction with complete elimination of some. During the recovery period of the next few days new branches developed. Further details of electric shock experiments will be published in a separate paper.*

Changes in Nerve Endings of the Distal Stump After Section

After a myelinated fiber is cut typical degenerative changes quickly become discernible in the endings which belong to the distal stump. In the example given (Fig. 12) within the first hour swelling of the endings was noticeable. Retraction, granulation, and liquefaction also took place. Later the branches became exceedingly tenuous and began to fragment.

* This paper has now been published in the *Proc. Am. Philos. Soc.*, 1942, *85*:168.

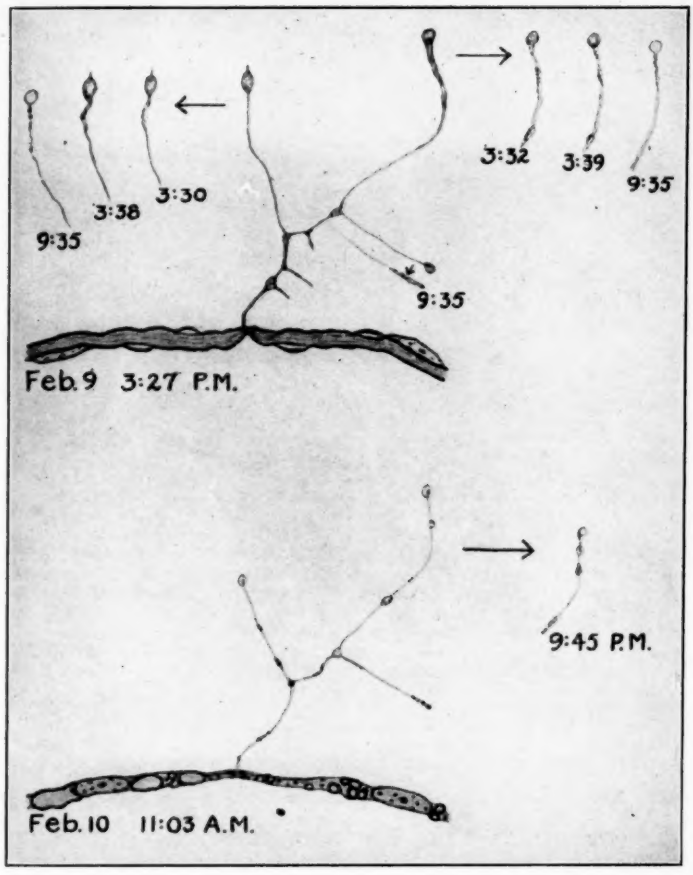

Fig. 12—Degenerative changes in nerve endings after nerve section. On February 9th at 3:03 P.M. a myelinated nerve fiber was cut at a point some distance proximally to the part illustrated. At 3:27 P.M. distinct changes in the nerve endings of the collateral branch were discernible. The ending at the left exhibited swelling and retraction club formation; the ending at the right exhibited swelling and thickening. Other changes became visible during the next six hours at the times indicated. On February 10th at 11:03 A.M. the three endings of the collateral branch were still visible. At this time the collateral was exceedingly tenuous. Myelin degeneration was visible. At 9:45 P.M. the short length of fiber sketched at the right was all that was left of the entire collateral. No trace of this was visible on February 11th.

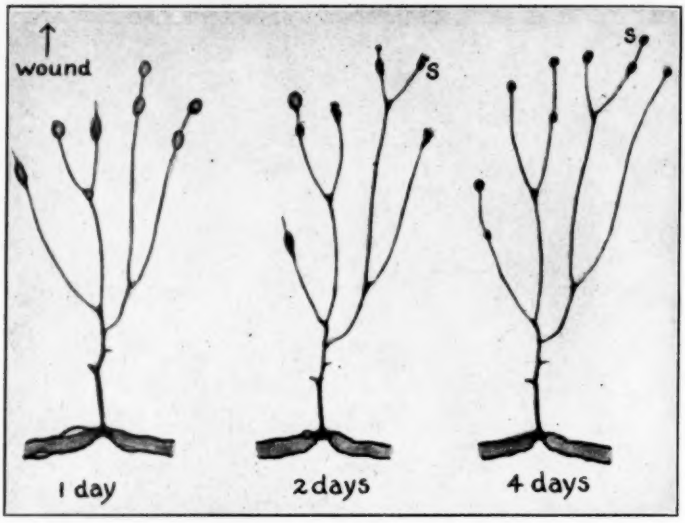

Fig. 13—Response of nerve endings near a wound during subsequent tissue regulation and repair. During the first day after a minor wound infliction a group of nearby nerve endings exhibited swelling and slight retraction. After two days growth cones were present on some of the endings. A new branch (S) was present. One ending, however, still exhibited swelling and one had retracted. After four days several endings had advanced toward the zone in which tissue repairs were taking place. All endings at this time were in the resting state.

It is clear that these degenerative changes in endings belonging to the distal stump bear a decided resemblance to the various irritative changes in endings, such as have been pointed out in many of the experimental treatments described above. In other words, the early changes in an irritated ending which is destined to recover are much like the early changes in a degenerating ending which is destined to be lost completely.

Changes in Nerve Endings Near a Wound As Cellular Regulation and Repair Ensue

If a local wound is made in the tadpole's tail by cutting, bruising, or other means, irritation of nearby nerve fibers takes place. Typical irritative changes of swelling and retraction may be seen readily in favorable cases. If the nerve endings under observation are too close to the wound, or if the wound becomes too extensive, complete degenera-

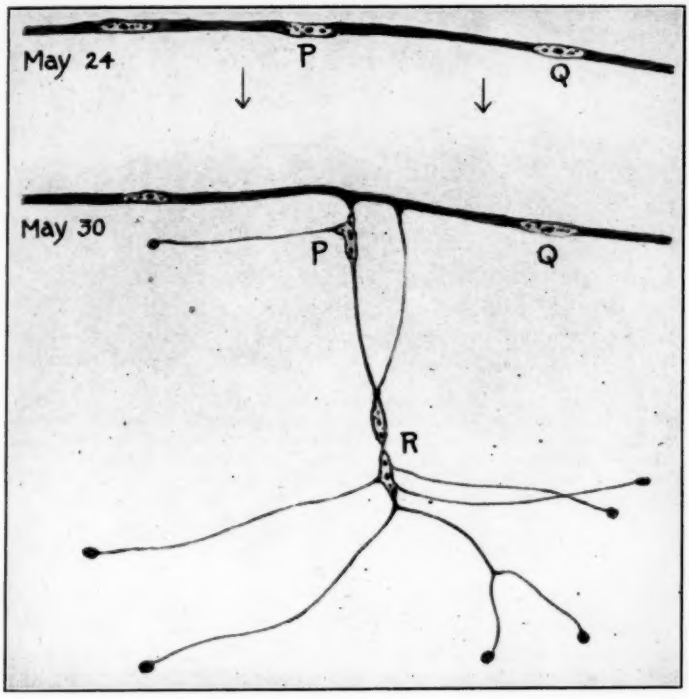

Fig. 14—The origin of collateral sprouts from a nerve following experimental denervation of an adjacent zone. On May 24th by appropriate sectioning of the tadpole tail fin a zone in the direction of the arrows was deprived of its nerve supply. The nerve figured was at the edge of the denervated region. Two new side sprouts arose, one on May 27th and one on May 28th. These grew and by May 30th had given rise to seven endings which supplied a part of the denervated zone. P, Q, and R mark the positions of neurilemma sheath cells. (The two sheath cells at R arose by division from a sheath cell which transferred from a degenerating nerve in the denervated zone.)

tion of endings may ensue. On the other hand, if the wound is too slight or if the endings are too distant, little or no change is visible. In suitable cases, however, excellent case histories of regressive and progressive changes in nerve endings from day to day may be obtained. In the example cited (Fig. 13) the endings of a terminal arborization exhibited definite swelling and retraction during the early period of injury. This was followed by recovery with growth and branching as wound repair proceeded.

Fig. 15—Origin of a nerve sprout correlated with mitosis of a nearby myoblast. A motion picture record of this case was obtained. A young muscle cell in division was located close to a small unmyelinated nerve and sheath cell. Immediately after the metaphase of mitosis a knob-like bulge appeared at the side of the nerve. This rapidly grew out as a new nerve branch, the tip remaining in contact with one of the daughter cells.

Evocation of Collateral Sprouts from a Nerve Following Experimental Denervation of Adjacent Territory

Obliteration of the nerve supply for a region quickly sets in motion recovery processes that will ultimately lead to the restoration of innervation of the affected region. An important feature of such recovery processes is the response of the nerves nearest the denervated zone. These may give rise to new sprouts which then quickly grow into the denervated territory. Presumably in some manner the denervated zone constitutes a local stimulus with sufficient influence to evoke new sprouts from nearby fibers which otherwise would not have given rise to them. In the example given (Fig. 14) a period of three days was enough to elicit the first new collateral branch from the adjacent nerve.

Nerve Fibers and Endings As Affected by Dividing Cells

Many instances have been recorded in which a nerve fiber exhibited definite changes during the division of a cell in close proximity. In one case (Fig. 15), as a young muscle cell divided by mitosis a new sprout arose from a nearby unmyelinated fiber. The sprout arose at a time of great agitation, namely, immediately after the dividing cell passed

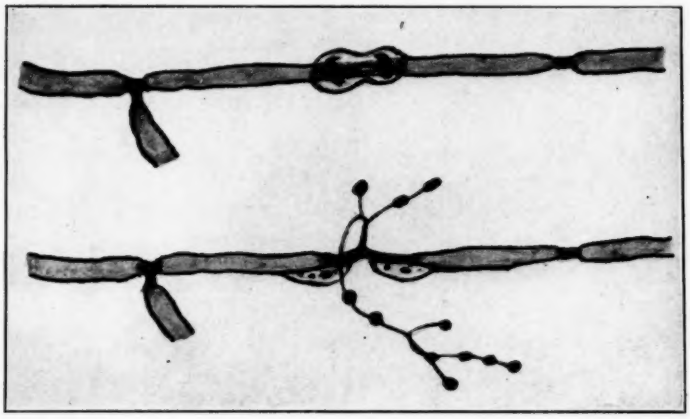

Fig. 16—Origin of a collateral set of endings from a myelinated fiber following sheath cell mitosis. In a young tadpole a sheath cell belonging to the penultimate myelin segment of a fiber underwent mitosis. The myelin became divided into two segments, each with a daughter sheath cell. Three hours after the mitosis a new young cluster of endings was visible, arising from the main fiber at a point between the two daughter sheath cells.

the metaphase stage. At this time the whole locus was in a state of activity, a feature clearly revealed by the fast motion ciné-photomicrographs that were obtained.

A dividing neurilemma sheath cell also constitutes a stimulus for the origin of new collateral nerve sprouts. I have watched several examples, including both myelinated and unmyelinated fibers, in which new branches arose following the metaphase. Motion pictures of dividing neurilemma cells vividly demonstrate that at such a time the nerve fiber swells and becomes more plastic. It is certainly stimulated mechanically, and possibly chemically, by the dividing cell. The case selected here for illustration (Fig. 16) shows the origin of a new collateral branch after mitosis of a neurilemma cell associated with a myelin segment.

Neurilemma cells also play a part in aiding regenerating nerve fiber tips to get past obstacles. Such aid is sometimes accompanied by mitotic division of the neurilemma cell. Examples of this have been presented in previous papers.[3,a,b,d]

Connective tissue cells in division may also cause activity of nerve endings provided they are in close juxtaposition. In two cases I have

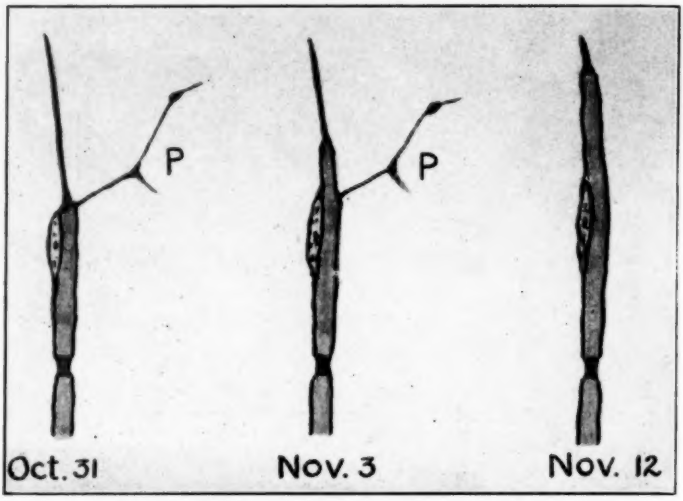

Fig. 17—Elimination of a collateral branch by advancing myelination. On October 31st a side branch (P) was present at the end of a terminal myelin segment. During the next three days the myelin advanced beyond the side branch, as indicated. By November 12th the side branch had become entirely eliminated.

seen a nerve ending of resting type become transformed into one of growing type, as a result of the motion of a contiguous dividing connective tissue cell. In one case the nerve ending tip advanced a short distance. In the other case there was no advance; after a brief period of activity characterized by slow movements of delicate pseudopods, the nerve tip again became transformed into the resting type with spherical end bulb.

Myelination as a Factor in Elimination of Nerve Endings

Myelination accompanies the growth and maturing of nerve fibers. One feature of this is the increase in the size and complexity of many of the terminal arborizations. Nevertheless, another important aspect of myelin sheath formation is the complete elimination of some collateral branches with their endings. I have observed many cases of this. In the example given (Fig. 17), a collateral branch was eliminated during growth of a myelin segment. In a previous paper[3,b] I have illustrated a similar elimination of a much larger collateral side branch

which had itself become ensheathed with a myelin segment.

The myelination process, however, does not always eliminate collateral branches which are not located at nodes of Ranvier. I have followed the histories of many such internodal collaterals and noted their survival up to the time at which metamorphosis took place.

Miscellaneous Observations

A few other observations of nerve ending adjustments may be mentioned briefly. Typical regressive changes in nerve fibers and their endings have been induced by heat (37°-40° C.) and cold, by relatively weak hypertonic sodium chloride solutions, by X-rays, by insulin extracts, and by foul aquarium water in which putrefaction is occurring. Recovery takes place after such irritants provided the injury is not too great.

Circulatory disorder is usually associated with nerve irritation. Chloretone, alcohol, metrazol, insulin, electric shocks, and hypertonic salt solutions all cause a slowing of the circulating blood. Nerve ending changes follow. Rarely, as in one case of chloretone treatment, an advancing growth cone of a regenerating fiber continued its activity and advanced an appreciable distance after the circulation in the entire tail had ceased.

As the time for metamorphosis of the frog tadpole approaches, the tail fin suffers increasing reduction in size. Irritative and degenerative changes become apparent in all of the tissues. Nerve fibers and their endings become affected. The nerve endings exhibit swelling and may suffer some retraction. Occasionally, however, growth and extension of an ending is visible even in a markedly reduced tail fin.

Connective tissue cells often block advancing nerve endings. Prolonged blocking may lead to nerve autotomy. Blocking of a rapidly regenerating nerve fiber tip may be followed by retraction and growth in a new direction, or by retraction and branching with growth of the branches in new directions past the obstruction.

Ciné-photomicrographs of Nerve Ending Adjustments

Ciné-photomicrographs of both normal and fast motion types have been obtained directly from living tadpoles. These record the typical changes in nerve endings under ordinary conditions and under conditions of irritation, injury, and recovery. Fast motion ciné-photomicro-

graphs are particularly valuable in revealing slow tissue changes. Prolonged day-to-day case histories are suitably shown by pictures taken at the normal rate. The motion pictures exhibited include, in addition to changes in nerve fibers and nerve endings, the activities of some other cells which are associated with nerve ending adjustments.

The subjects of some of the pictures follow.

1. Rapidly growing nerve tip blocked temporarily by a connective tissue cell process.

2. Rapidly growing nerve tip advancing through the tissues after passing a blockade formed by two connective tissue cells.

3. Two growth cones diverging as they advance.

4. Retraction of a growth cone (two examples).

5. Retraction of an actively advancing nerve tip induced by alcohol treatment, followed by resumption of growth along a new route with the restoration of normal conditions.

6. Reactions of the myelin sheath, axis cylinder, and nerve endings during and following alcohol treatments.

7. Swelling, retraction, recovery, autotomy, and degeneration of nerve endings in alcoholized tadpoles.

8. Degeneration of an entire cluster of nerve endings caused by severe metrazol-induced injury, followed by regeneration of a new nerve ending pattern at the former site.

9. Epithelial cells (overlying irritated cutaneous nerve endings) displaying rapid movements of readjustment, three hours after metrazol treatment.

10. Lymphocyte movements within the neurilemma of an adjusting nerve trunk after metrazol injury.

11. Continuous, though slow, advance of a cutaneous ending over a four day period in a tadpole nearing metamorphosis.

12. The retraction of an ending, initiated by starvation, continuing even after normal food conditions have been restored.

13. The genesis of a nerve branch in close proximity to, and probably stimulated by, a dividing myoblast.

14. Nerve adjustments associated with division and movements of sheath cells.

15. Growth of fibroblast process following fibroblast mitosis (for comparison with nerve tip growth).

16. Markedly swollen nerve endings on the day following severe

electric shock treatments.

17. Electrical injury of nerve endings with swelling and degeneration, followed during the next four days by nerve ending extension and establishment of new connections.

18. Clotting at the muscle-tendon junction of a fiber of striated muscle during electrical injury.

19. Two case histories showing successive retraction and advance of the same individual nerve endings, correlated with alternating periods of starvation and good nutrition.

20. Chronic swelling and autotomy of an end bulb of a fiber in a starved tadpole, followed by development of an abortive growth cone tip.

21. Comparison of macrophage activity during ingestion of a swollen degenerating nerve ending and during ingestion of an extravasated red blood cell.

Discussion

A few points suggested by the foregoing observations may be discussed briefly. It is clear that while there are many varieties of irritation and injury, nerve fiber endings display only one general pattern of changes. This includes swelling, retraction, and variable amounts of degeneration. Likewise, the changes during recovery follow one general pattern. This includes reduction of swelling, growth and branching of endings, and the establishment of new terminal positions.* The point has already been made that the end arborizations are free and unsheathed. There is, therefore, no duplication of an original pattern of nerve endings as a part of the recovery process following a period of regressive change. This feature makes for flexibility. Nerve endings are not absolutely fixed and stable. They adjust themselves to changing stresses and strains.

It should be emphasized that my observations deal only with free unsheathed endings, peripherally located. This type, however, is present in enormous numbers in the central nervous system, taking part in the synapses between nerve cells. Cajal[1,4] has given us many illus-

* Nerve endings represent the part of the nerve cell that is most distant from the cell nucleus. In general, it is true of cells having long processes that the most peripheral parts suffer regressive change first. I have watched irritated connective tissue cells, pigment cells, and the endothelial cells of blood and lymph capillary sprouts. During the phases of irritation and recovery, the tips of the processes of these cells exhibit changes much like those of nerve endings. The behavior of the nerve endings, therefore, is not unique.

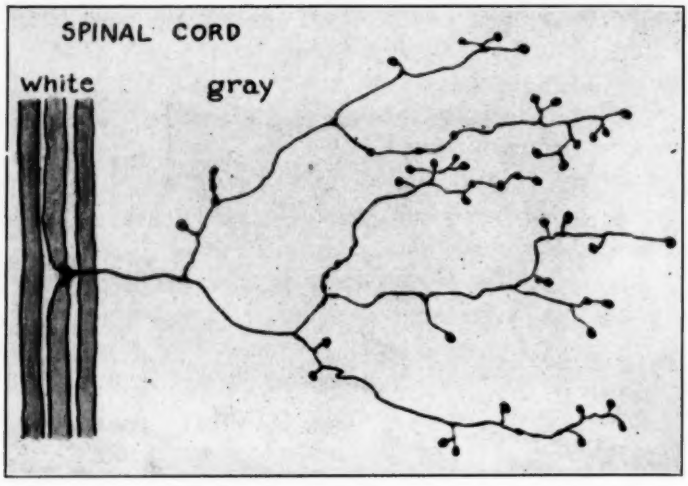

Fig. 18—A terminal arborization of nerve endings in the gray matter of the cat's spinal cord, arising from a collateral branch of a myelinated fiber in the white matter. Redrawn from Cajal, representing two illustrations combined. This illustration of synaptic nerve endings in the central nervous system is strikingly similar to that of peripheral nerve endings at the skin (cf. Fig. 1).

trations. In the example reproduced here from the cat's spinal cord (Fig. 18) is shown a collateral branch with its terminal arborization in the gray matter. This tree of free nerve endings is quite like those in the frog tadpole which have formed the subject of my investigations. Similar end arborizations are present also in the brain.

Unfortunately direct observations cannot be made on nerve endings located within the central nervous system. Case histories of individual endings, therefore, have never been recorded. The fixed preparations of Cajal,[1] however, clearly show that a centrally located nerve ending does not always have a resting end bulb tip. It may have a swollen irritated tip, a growth cone tip, or a retraction club tip. Endings exhibiting degeneration and autotomy are also apparent.

Accordingly, there is little doubt in my mind but that the free nerve endings of the central nervous system may undergo changes during irritation, injury, and recovery much like those of peripherally located endings. This is significant because of the role such endings play at synapses. The conclusion seems justified that some flexibility in synap-

tic connections is possible; that certain changes may take place from time to time with the elimination of some old synapses and the establishment of some new ones.* I have already proposed such an anatomical mechanism as a basis to account for the changed mental outlook that sometimes occurs in metrazol-treated human beings.[8,t]

Not all synapses are alike. In some cases there is extensive contact between the two nerve cells concerned through complex interlacing of their processes. In other cases there is relatively limited contact, the endings of one nerve cell merely touching at one or more places the endings, or processes, or cell body of the other nerve cell.** The former type of synapse would probably be more stable than the latter type.

Nerve fibers which supply striated muscle are usually ensheathed with neurilemma all the way to the muscle fiber end plate.[7] Likewise, nerve fibers which end in special sensory corpuscles of the encapsulated type are usually ensheathed with neurilemma all the way to the corpuscle.[7] Such endings would also be more stable than those of the free type. If injury did take place the surviving neurilemma would function to direct the regenerating fiber along the original path to the end structure concerned.

In conclusion, it seems probable to me that nerve ending changes accompany many bodily disorders of both acute and chronic types; such, for example, as during severe infectious diseases characterized by toxins and fever, during states of marked hormonal imbalance, during chronic vitamin deficiency, during marked circulatory and kidney disturbances, and during the gradual tissue degeneration that characterizes the approach of senility. In man, the synaptic changes in the brain probably would be of most significance in accounting for whatever mental changes might accompany such general bodily disorders.

Summary

1. The nerve endings of terminal arborizations of myelinated fibers in frog tadpoles, though relatively stable, may undergo adjustments under both normal and experimental conditions. The principal changes exhibited are swelling, retraction, extension, branching, autotomy, and

* Extensive regeneration of nerve cells and fibers does not occur in the brain and spinal cord, as is well known. Nevertheless, Cajal[1] presents many illustrations which lead me to the conclusion that the delicate branches of terminal arborizations readily adjust themselves either progressively or regressively.

** I agree with the "contact idea" as to the nature of the synapse. Strong evidence for this has been presented recently by Bartelmez and Hoerr[5] and by Bodian.[6]

degeneration. Essentially similar nerve ending adjustments result from slow chronic changes and from rapid acute changes.

2. During a period of general bodily growth, a terminal arborization increases in the size and number of its branches. From time to time individual endings may become swollen. They then may extend by growth cone activity, or retract, or suffer degeneration. Sometimes autotomy of a branch, or a part of a branch takes place. Some endings of cutaneous fibers are aberrant and grow in a deep, instead of a superficial, direction. Such branches become eliminated by retraction, or degeneration, or as further growth takes place they may change their course in such manner as to extend in a superficial direction.

3. Starvation induces regresssive changes of swelling, retraction, and degeneration. Successive retraction and growth of the same individual endings may be induced experimentally by imposing on tadpoles alternating periods of starvation and good nutrition.

4. Treatments of tadpoles with alcohol or with chloretone may cause typical regressive changes in nerve endings. With such treatments alternating with recovery periods, regressive and progressive changes may be induced successively in individual nerve endings. The growth cone tips of rapidly regenerating nerve fibers are particularly susceptible to experimental modifications of this sort.

5. At rest the end bulb (bouton) at the tip of a branch is in the gel state. During irritation it undergoes increasing change toward the sol state as swelling ensues. During recovery it returns to the gel state. Retracting and growing tips are in an intermediate state.

6. During regeneration after injury, nerve fibers and their branches duplicate an original pattern only as far as they are ensheathed by the original neurilemma. Free unsheathed nerve endings, therefore, establish new connections during recovery.

7. Nerve fibers and their endings display marked changes of irritation and injury in tadpoles subjected to metrazol, or to insulin, or to electric shocks. With recovery after each of these treatments the patterns of individual nerve ending clusters may be quite different from the patterns before treatment.

8. Nerve ending changes are also apparent after treatments with hypertonic sodium chloride solutions and after exposure to moderate rise in temperature.

9. The changes in irritated or slightly injured nerve endings which

will recover resemble closely the early changes in nerve endings undergoing trophic degeneration which will not recover.

10. Local wounds sometimes stimulate adjustments of nearby nerve endings in uninjured territory. Swelling, retraction, extension, and branching of endings may result.

11. A denervated zone may evoke new side sprouts from nearby uninjured nerve fibers. Collateral innervation may thus be established.

12. New nerve sprouts sometimes appear on fibers that are contiguous to dividing cells (neurilemma cells, myoblasts, and fibroblasts). This takes place after the metaphase, during a time of marked agitation.

13. The advance of the myelin sheath on a fiber is a factor in causing elimination of some branches by retraction or autotomy. Even large branches with myelin segments are occasionally eliminated.

14. Free nerve endings which are present in large numbers in the central nervous system probably undergo adjustments similar to those of free cutaneous endings. Synaptic changes would be possible, therefore, from time to time. Thus, changes in brain synapse patterns might be brought about as a result of shock treatments, severe intoxications and fevers, and marked nutritional or hormonal imbalance. Such changes also probably accompany ordinary growth and maturation of the brain.

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THE DEVELOPMENT OF NEUROLOGICAL SURGERY IN NEW YORK CITY DURING THE PAST TWENTY-FIVE YEARS*

With Remarks on Advances due to Experiences in the First World War

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IN our city and country, neurological surgery began to be recognized as a special field only a little more than twenty-five years ago. Before that time and within the memory of some of us, forty to fifty years ago, operations upon the central nervous system were rare and were performed by the general surgeon. Some of the earliest operations for tumor of the brain were performed in New York City by general surgeons, Drs. Charles McBurney at Roosevelt Hospital, Arpad G. Gerster at The Mount Sinai Hospital, and Andrew J. McCosh at the Presbyterian Hospital. Just fifty years ago, in 1892, Frank Hartley described the operation for the intracranial exposure of the Gasserian ganglion which was known for many years as the Hartley-Krause operation.

It was natural that the neurologist of those days felt that he should supervise any operation on the central nervous system that was performed by the general surgeon. Not quite fifty years ago, in 1893, M. Allen Starr, Professor of Neurology at the College of Physicians and Surgeons, published a volume on the surgery of the brain. You will note the interesting fact that a book on brain surgery was written by a neurologist. In this book, Dr. Starr gave the following quaint advice to the surgeon: "It is an absolute requisite of success in cerebral operations that every detail of aseptic surgery should be carried out to perfection. It is useless to make elaborate preparations, to sterilize instruments and to apply antiseptic solutions to the hands, if in the midst of the operation the surgeon stops for a moment to adjust his septic eyeglass, or to

* Read at the combined meeting of the Section on Neurology and the New York Neurological Society, March 10, 1942. This paper was also in part read at a dinner to celebrate the 25th anniversary of the foundation of a neurological service at Bellevue Hospital.

blow his nose on a septic handkerchief without subsequently washing his hands again." This was perhaps good advice but Dr. Starr spoiled it all by his next remark: "By covering the hand with a wet aseptic towel, the surgeon can safely handle anything he desires." It is hard to realize that this crude advice was given less than fifty years ago.

Even as recently as seventeen years ago, the neurologist had the point of view expressed, for example, by Dr. Mills of Philadelphia, that one of the functions of the neurologist is to *superintend* and *direct* operative procedures on the brain and spinal cord by the surgeon.* At about the same period, a similar viewpoint was expressed to me in writing by another eminent neurologist: "that the function of the surgeon was to do the technical work and to make the opening in the skull or spine in the area mapped out by the neurologist, and that the surgeon should not attempt to make a diagnosis or to localize the growth." Fortunately, *tempora mutantur et nos mutamur in illis!* Fortunately, also, the neurological surgeon has learned something of neurology so that he is no longer looked upon merely as a technician. Perhaps the change may be appreciated by the evidence that in recent years an increasing number of neurological surgeons have been elected to membership in the American Neurological Association: Twenty-five years ago, in 1917, there were 121 active members in the Association of whom 4 per cent were neurological surgeons; in 1925, the percentage was 5; in 1935, it was 10 and in 1941, it was 15 per cent. This steady increase in the number of neurological surgeons in the American Neurological Association was a cause for perturbation of some of the members. One of them wrote to the Council of the Association and asked how long it would be, at the same rate of increase, before the American Neurological Association would consist mainly of neurological surgeons! When that letter was read at the Council meeting, one of the members calculated that at the same rate, in 1967, more than one-half of the members would be neurological surgeons!

A neurosurgical service can be developed only in a special hospital or in a general hospital in which there are special neurological and neurosurgical beds. A capable operating team cannot be developed in an institution in which a major operation upon the central nervous system is performed only a few times a year. In most of the general hospitals in New York City, until about twenty-five years ago, there

* Semi-Centennial Volume of the American Neurological Association, 1875-1924.

was not a sufficient number of patients with diseases of the nervous system to justify a special neurosurgical service. If the Neurological Institute (which is a special hospital) was excepted, there were at that period active neurosurgical services only at The Mount Sinai Hospital and at Bellevue Hospital in both of which there were special wards for patients suffering from diseases of the nervous system. Recently, departments for the surgical treatment of diseases of the nervous system have been developed at the New York, the Brooklyn Jewish and to some extent in a few smaller hospitals. Also, it is of interest to note that until recently, the title of the neurological surgeon—if he was a member of the faculty of a medical school—was "Professor of Surgery." Dr. Cushing was professor of general surgery at Harvard and Dr. Frazier was professor of general surgery at the University of Pennsylvania although both limited their work almost exclusively to neurological surgery. However, about 21 years ago, Columbia University at the College of Physicians and Surgeons, established a full chair for neurological surgery with a seat on the faculty of the Medical School.

Neurological surgery has developed, as was logical, as an offshoot from general surgery, and the emergence was due to a process of education of the general surgeon, the neurologist, the physician and the layman. Actually it required only a few decades for the new specialty to be generally recognized. In the beginning, a few general surgeons began to devote themselves to neurology and to operations upon the nervous system. There is, perhaps, a certain disadvantage in what is happening today, i.e., that many young men receive their training in neurosurgery and become neurological surgeons without having had a thorough basic experience in general surgery. While it is true that a neurologist may learn to do his own operating (as was done by the late Ottfried Foerster in Breslau, Germany and by Clovis Vincent in Paris), a groundwork in general surgery is of no little value.

Most of the younger neurological surgeons of our day have received their training in one of the neurosurgical centers in this country. A few of the older ones began to practice in the special field after an experience with injuries of the brain, spinal cord and peripheral nerves in the first World War. While a knowledge of traumatic surgery is of value, more than that is needed for the practice of neurological surgery in civil life. However, we learned much from the experiences gained in the first World War.

For example, in high explosive and bullet wounds of the skull and spine, the method of *débridement*—the excision of lacerated soft and bony tissues—proved to be of great value for the prevention of secondary infection of the brain or spinal cord and their meninges. If the area in which infectious material has been implanted can be excised, the wound may often be closed with resultant primary union. The method of *débridement* was most useful in the treatment of wounds of the extremities and of the peripheral nerves. The conflict that is now raging will no doubt, as in the first World War, produce a large number of bullet and high explosive wounds of the upper and lower limbs. In his very recent report of experiences at Pearl Harbor, Dr. John Moorhead made special reference to the high frequency of wounds of the nerves of the extremities. During the first World War, the method of *débridement* and the use of chlorine solutions (Carrell-Dakin treatment) greatly diminished the frequency of wound infections. However, it may not be amiss to call attention to one danger of *débridement*. Having had occasion to operate upon a large number of soldiers with peripheral nerve injuries after they had been invalided home from the battlefronts, I learned that occasionally evidence of complete interruption of the function of a large nerve followed only after the mass extirpation of lacerated soft tissues. In some of the cases, one was led to suspect that the neural lesion was produced by the surgeon. The functions of a large nerve may be preserved even though the nerve traverses an area that is infected or even an area of actual suppuration. Therefore, especially with the sulfathiazole treatment of wounds, every effort should be made by the surgeon to preserve nerves which have not been injured and those that are only traumatized, especially those nerves, such as the ulnar in the upper and the sciatic and its branches in the lower limbs, in which regeneration after nerve suture is poor.

It is to be hoped that the follow-up of patients in whom nerve transplants have to be used to bridge nerve defects will be better than that after the first World War. After the former conflict, there was not an efficient follow-up, and our knowledge is still meager regarding the final results in these individuals in whom the separated nerve ends could not be united by suture and transplants were used. In these patients, many types of operation were tried but we do not know which methods gave the best results.

Aside from these surgical matters, the neurologist learned much from

the experiences of the former conflict. Thus, the *coup-de-grace* was given to the so-called Bastian-Bruns law regarding the symptoms and signs of complete transverse lesions of the spinal cord. You will remember that for many years the symptoms of a complete transverse lesion of the spinal cord in man were supposed to consist of permanent loss not only of sensation and voluntary motor power below the level of the lesion but also of persisting absence of all tendon and cutaneous reflexes. We now know that after a certain period there is a return of spasticity and of reflexes without, of course, any return of sensation or voluntary power. The experiences of the first World War increased our knowledge of the location of functions in different parts of the brain and spinal cord, of mass reflexes and of automatic activity of the urinary bladder.

When one looks back upon neurological surgery as it was in the early days of the specialty and compares it with the work of today, the differences are great and impressive. At that time we had not learned that the "enacting clause" in operations for tumor of the brain was the diminishing of the increased intracranial pressure. Can you imagine the difficulties of the neurosurgeon before we learned of the value of hypertonic solutions and of the method of puncture and evacuation of fluid from the ventricles and subarachnoid cisterns in order to lessen intracranial tension? In those days the patients were always anesthetized—usually by ether which by itself raises intracranial pressure. We had to learn that these operations could and should be performed under local infiltration anesthesia—a method first recommended for cranial surgery by Dr. DeMartel of Paris. In this country, I believe, the first cranial operations for tumor of the brain under local anesthesia were performed by myself at the Neurological Institute of New York. As you know, local anesthesia is now used for the majority of cranial operations and it is especially effective when the patient has received avertin before he is brought to the operating room.

During the past decades, great advances have been made in the methods of hemostasis: First came silver clips, then the use of muscle, and finally the high frequency current. Many improvements were made in the methods of making bone flaps and in the technique of exposure of tumors on the under surface of the brain; of growths in the cerebellopontine angle and in the cerebral ventricles. The methods of excision of infiltrating tumors of the brain have become more and more

radical so that today no neurosurgeon would hesitate to excise the greater part of one cerebral or cerebellar lobe. It is very questionable, however, whether there is ever any justification for the total or subtotal removal of a cerebral hemisphere.

I have wandered somewhat afield and away from the story of the development of neurological surgery in New York City. During the past 25 years, New York City has had twenty-three surgeons who limited their work to the surgery of the nervous system. With the possible exception of two of these, all of the surgeons have had a training in neurology and neurosurgery, either in one of our local institutions or in a neurosurgical clinic in some other city. It may be of interest that we have had one woman specialist in this field. At the present time there are in the greater city of New York sixteen active neurological surgeons and several younger men who are beginning to devote themselves to the specialty.

During the first part of the 25 year period, there were neurosurgical departments at the Neurological Institute and at Bellevue and The Mount Sinai Hospitals. The service at the Neurological Institute was directed by me, and associated with me were Drs. Alfred S. Taylor, Byron Stookey, James H. Kenyon, Clement Masson, Wilder Penfield, Dorothy Klenke, Leo M. Davidoff, Edwin Deery, Fritz Cramer and Earl D. Brewer. When I retired from the ward service, Dr. Stookey was appointed to take charge, Dr. Davidoff resigned in order to become surgical director of a Brooklyn hospital, Dr. Deery resigned, and Dr. John Scarff was appointed a member of the surgical staff. Previous to this period, Dr. Penfield had resigned in order to become the Director of the Montreal Neurological Institute, Dr. Klenke had resigned and the Neurological Institute had lost Dr. Brewer and Dr. Kenyon through death. In 1938 Dr. Tracy J. Putnam was appointed chief of the neurological and neurosurgical services of the Neurological Institute.

At Bellevue Hospital the neurosurgical service was in charge of Dr. Taylor, and at various times there were associated with him Dr. Stookey and Dr. J. J. King. Later, the work at Bellevue was done by Dr. King, Dr. Scarff and lately by Dr. Lawrence Pool.

Up to 1927, the neurosurgical service at The Mount Sinai Hospital was in my charge and that of Dr. Ira Cohen; upon my resignation, Dr. Cohen became the head of the service with Dr. Kaplan and Dr. Sidney Gross as associates.

Although there was no special neurosurgical department at the Presbyterian Hospital, considerable work was done in that institution by Dr. Penfield and Dr. William Cone before they left for Montreal and the histological and pathological studies made by them in the laboratory for neurocytology organized by Dr. Penfield deserves special mention. At the Brooklyn Jewish Hospital, Dr. Davidoff a few years ago organized a neurosurgical service, and he has been doing a large amount of operative work in that institution. In Brooklyn, considerable neurosurgery has also been done in several hospitals by Dr. Jefferson Browder, and some by Dr. Anatole Kolodny.

Recently, an efficient department for the operative treatment of diseases of the nervous system is being developed by Dr. Bronson Ray at New York Hospital, and during the past two decades some operations on the nervous system have been done in other hospitals by neurosurgeons at St. Luke's Hospital and at the Post-Graduate and the Polyclinic Hospitals and a few other institutions.

A certain number of operations for fractures of the skull and the spine were and are still being performed by general surgeons at various hospitals in our City, but the general tendency has been—whenever and wherever possible—for fractures of the skull and the vertebral column to be cared for by the neurological surgeon.

During the early years of the 25 year period, abscess of the brain complicating middle ear disease was cared for and operated on by the otologist. As the field of neurological surgery became more specialized, these patients were more often referred to the neurosurgeon and today most of these operations are performed by the surgeon who specializes in this field.

Finally, I may be permitted to give a short account of some of the contributions to neurology and neurosurgery made by the special workers in the latter field in our city:

A number of years ago, Dr. Alfred S. Taylor, who by the irony of fate recently succumbed to an infiltrating tumor of the brain, developed the technique of operations for birth injuries of the brachial plexus, and he also described the operation of unilateral laminectomy and devised ingenious instruments for that operation. Much of Dr. Taylor's work was done at Bellevue Hospital and at the Neurological Institute. Also, on the special service at Bellevue Hospital, Dr. J. J. King did important work on the methods of operation for abscess of the brain.

I have already referred to the valuable studies on the glia by means of the newer staining methods that were made by Dr. Penfield and Dr. Cone.

I think that it is fair to state that to the development of the surgery of the spinal cord, New York surgeons made important contributions. The technique of the operation of laminectomy was developed by them, and they added much to our knowledge of the clinical features and the diagnosis of tumors and other lesions of the spinal cord and its membranes. The clinical symptoms and surgical treatment of the so-called giant tumors of the conus and cauda equina—which are most often ependymomas—were first described by neurosurgeons of our city and the same is true of varicosities of the spinal blood vessels and of extradural cysts of the spinal cord.

The improvements in the methods for performing manometric tests for the determination of the presence or absence of spinal subarachnoid block were no insignificant contribution. The refinements in the methods for testing the patency of the spinal subarachnoid space were made by Dr. Stookey and his collaborators. To neurosurgeons of our city also belongs the credit for having devised the method for the exposure of the anterior surface of the spinal cord in order to remove tumors from in front of the spinal cord and to treat other lesions in that situation.

It was formerly believed that the malignant tumor of the brain, which is now called glioblastoma multiforme,* occurred most often in the frontal parts of the cerebral hemispheres and especially often on the left side. The study of a large number of cases at operation and postmortem convinced us that the growth is most frequently situated in the parietal lobe although it often extends forward to involve the frontal lobe and more especially the inferior part of the temporal and frontal lobe of the brain. With another investigator, one of us called attention to the fact that glioblastoma multiforme of the brain frequently runs a very rapid course—a course quite different from that of most cerebral growths. The history of the patient's illness may be of only one or a few weeks duration and the symptoms run an acute course.

Profound disturbances in motor power and sensation and advanced mental deterioration often come on very rapidly. For this reason, we

* For reasons that have been frequently expressed in print, I still believe that the term "spongioblastoma multiforme," originally given to the growth by Globus and Strauss, is preferable.

TABLE I

RESULTS OF OPERATIONS IN 83 PATIENTS WITH GLIOBLASTOMA MULTIFORME OF THE BRAIN

Death within 4 weeks	44	53 per cent	}	84 per cent
" " 4 months	10	12 per cent		
" " 1 year	16	19 per cent		
" " 1-2 years or more	9	11 per cent		
Living 4 months after operation	1			
" 8 " " "	1			
" 10 " " "	1			
" 22 " " "	1			

suggested that these growths might be called "acute" brain tumors. I think that there is some doubt whether the glioblastoma multiforme is a true neoplasm or whether it is a tumor formation resulting from an intense glial reaction to some noxious agent. If this point of view should be shown to be correct, then it is clear that in the future the proper treatment of this type of tumor will rarely be surgical. The results of the operative treatment of glioblastoma multiforme are poor and relatively few patients survive for more than one year. This is shown, for example, by the results in the series of cases presented in Table I—results which about correspond to those obtained in other neurosurgical clinics.

Another type of tumor which we have studied is the midline posterior fossa medulloblastoma which occurs so often in childhood. Many attempts have been made radically to extirpate these growths, but they can rarely if ever be entirely removed because of their vascular attachment in the lower part of the fourth ventricle. This type of tumor is very radiosensitive, and we have shown that as good if not better results can be obtained if the effort is not made to remove the growth. In most instances, by a wide suboccipital decompression with removal of only sufficient tumor tissue for pathological verification, followed by thorough Roentgen-ray therapy, as much will be accomplished and relief will last as long as after the attempt to remove the growth entirely. Moreover, if one takes into account the higher operative mortality of an attempted radical operation, the total results of the operative treatment of the medulloblastoma in the posterior cranial fossa are better with conservative surgery and radical Roentgen therapy.

The early diagnosis of benign tumors underneath the frontal lobes of the brain—more especially the olfactory groove, cribriform plate and

sphenoid ridge meningioma—is important for their surgical treatment. When these growths have reached a large size, the difficulties and dangers of their removal are much increased, and in some instances the large growths can not be entirely removed. We, in New York City, have been greatly helped by a New York roentgenologist, Dr. Cornelius G. Dyke, and his studies of the basal arachnoid cisterns after the injection of air or oxygen by the lumbar route. With a neurological surgeon Dr. Dyke was able to demonstrate that many subfrontal meningiomas, especially those which originate from the dura over the mesial end of the sphenoid ridge, can be recognized and be removed when they are still small—weighing only a few grams.

That the diagnosis of some tumors of the spinal cord can be made by careful measurements, on Roentgen films of the spine, of the distances between the pedicles, was demonstrated by the same roentgenologist with a New York neurosurgeon. Studies of a large number of Roentgen films of the spine were correlated with the operative findings and we learned that certain spinal growths regularly produce a localized enlargement of the spinal canal which can be recognized when the interpediculate distances are carefully measured. By these measurements it was possible to demonstrate that the spinal meningiomas rarely, and the spinal perineurial fibroblastomas frequently, cause localized enlargements of the interpediculate distances. An enlargement of the vertebral canal extending over several vertebrae is characteristic of the extradural cysts and of the so-called giant tumors of the conus and cauda equina.

The clinical picture of high cervical spinal cord tumors which project through the foramen magnum was first described by a New York surgeon and a neurologist. Attention was called to the fact that in operations for these growths it is always necessary and advisable partly to expose the structures in the posterior cranial fossa by the removal of some of the occipital bone. If this is not done, a part of the growth above the level of the foramen magnum may be missed altogether—an unfortunate occurrence which happened in our first case and which taught us a valuable lesson.

Finally, one may ask: what of the future? That old Roman, Cicero, said that "in no function do human beings approximate the Gods more closely than in bestowing health upon their fellowmen." We must change methods or improve them as soon as we learn that we are using a procedure by which little or nothing is being accomplished. There

are some diseases of the nervous system for which surgery has been able to do little or only to palliate, and for these, new surgical methods must be sought for or the treatment must not be surgical. Thus, it is probable that when the diagnosis can be made—and it can be made in many instances—fewer operations will be done in the future for the malignant glioblastoma multiforme. Future therapy may be radiological or perhaps serological. In purulent infection of the meninges the therapy of the future may not be surgical. The isolation and synthesis of many of the vitamins by the biochemists have opened up a large field for clinical investigation and "these discoveries of the biochemists, if applied to the prevention and treatment of diseases of the nervous system, may be compared in importance to the discoveries in bacteriology made 40 to 50 years ago." Is it too optimistic to expect that some diseases of the nervous system which produce great disability, such as spasticity and tonic and clonic seizures, and for which surgical procedures are being attempted, will in the future be prevented or treated by medical means? This does not mean that neurological surgery will not continue to advance. We can not expect that the progress in operative methods and technique in the next twenty-five years will be as great as that made in the same period that has passed. The further progress of neurological surgery will be more slow, but new procedures and greater refinements of technique are certain to come.

WHAT EVERY PHYSICIAN SHOULD KNOW ABOUT CROSS-EXAMINATION

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PHYSICIANS are in court almost as frequently as lawyers. It is said that court records in New York City would reveal that suits involving personal injuries constitute about 70 per cent of the litigation. Since each side will have at least one physician, there are at least as many doctors as lawyers in every such case. This situation is not peculiar to New York City; it is reported that it exists throughout the United States. Furthermore, personal injury actions are not the only species of litigation where physicians are required. Doctors testify in goodly numbers in will contests involving insanity, in various criminal trials, such as assault, rape, homicide and the like, and in health, accident and disability insurance cases. All in all, it appears that the physician is quite a "man about court." Wisdom would appear to dictate that physicians should familiarize themselves with the problems of witnesses.

A famous English barrister once said, "There is never a cause contested, the result of which is not mainly dependent upon the skill with which the advocate conducts the cross examination." This statement was made in the days when flowery oratory was in vogue and when it played a very important part in the trial of cases. Today, that form of oratory is passé, and it plays a minor role in litigation. If cross-examination was the decisive factor in litigation in those days, it is doubly true today. Though the quotation set forth here was made to convince lawyers to become proficient in the art of cross-examination, it is equally appropriate for witnesses. This is especially so for physicians because more is expected from the professional expert by the triers of the facts. Any person who takes the stand will make a better and more convincing witness if he becomes familiar with the methods utilized by cross-examiners.

All witnesses are subjected to both direct-examination and cross-examination. Both terms should be defined and explained simultaneously

if the process of cross-examination is to be fully appreciated.

Law dictionaries define direct-examination as the examination of a witness by a lawyer who calls the witness to the stand and who first examines him, and they define cross-examination as the examination of such witness by the adverse lawyer, after the conclusion of the direct examination. Webster's Collegiate Dictionary defines "Cross-Examination" thus: "To examine or question, especially as a check to a previous examination."

The true significance of cross-examination and the purpose and utility of the process and the reasons for its effectiveness can be fully appreciated and understood only if it is examined in the setting in which it is used and of which it is an integral feature—the trial of a case in court. Cross-examination is a practical art and it is natural that it fitted and adapted itself to its setting.

The principal feature of this setting, in so far as cross-examination is concerned, is that the direct examiner presents only such evidence, and calls only such witnesses, and asks only such questions as will favor the side of the examining lawyer. The direct examiner will ask for nothing except facts favorable to his own side. The direct examiner does not ask the witness to disclose all that he knows, and the witness does not do so. If the examination of the witness stopped at this point and no attempt was made to find out what else he knows, the testimony would probably present half truths only. The direct examiner does not ask questions that might impair or discredit the story or the witness that he presents to the judge and jury. The factors that might weaken the original testimony or that might lessen the credit of the witness might remain hidden if the examination were to end there. The best person to make the search for what remains hidden, the undisclosed remainder, is the person who is most interested, the opponent. Thus, when the direct examination is concluded the cross-examiner is given an opportunity to complete the picture—to develop and bring to light those facts and circumstances which may have been suppressed on the direct examination. If any facts unfavorable to the direct examiner's case really exist and these are to be learned, the cross-examiner must ferret them out.

The practical effect of all this is that the cross-examiner will probe only for such facts as will be unfavorable to the direct-examiner's case. Since partisan counsel will, between them, endeavor to bring forth all

the favorable and unfavorable facts concerning each side, a fair appraisal of the witness and the stories should ultimately result.

Whenever partisans present evidence, it is desirable, before any evidence is accepted as wholly trustworthy, that it be subjected to testing and checking. The test can be effected by subjecting the offered evidence to a scrutiny and analysis calculated to discover and expose, in detail, its possible weaknesses and thus to enable it to be estimated at no more than its actual value. That is the function of a cross-examination and it is called the finest weapon ever invented to discover truth.

The ultimate objective of a cross-examination is to extract from the witnesses whatever may be unfavorable to the direct examiner's case. The unfavorable matter would be of two varieties, (1) facts that support the cross-examiner's contentions, and (2) facts that discredit the witness or the story or that weaken the direct examiner's case.

To extract each unfavorable fact constitutes a separate and distinct objective for the cross-examiner in every case. The nature and character of the unfavorable facts will vary with the case and the witness. The number of possible unfavorable facts is limitless.

An illustration will serve to clarify and explain this statement: A case of assault will be assumed. The sole disputed issue is, "Did defendant shoot plaintiff at 3 A.M. on November 30, 1939 in Grand Central Station?" The plaintiff contends that the defendant did this, and the defendant denies it. Though a single issue exists, it contains three elements: (a) did the defendant shoot the plaintiff, (b) did the shooting occur at the Grand Central Station and (c) did it occur at the time in question. Separate witnesses may be called to prove each element of, or the whole of, this proposition. Witness Roe is called by plaintiff and says that plaintiff and defendant were at Grand Central Station immediately before 3 A.M. on November 30, 1939. The witness is then turned over to the cross-examiner for questioning. The cross-examiner will ask himself: "What facts can be extracted from witness Roe that will be unfavorable to the plaintiff's case?" A very meager list of facts that would tend to support the defendant's proposition, or that would tend to discredit witness Roe, or the statement that plaintiff and defendant were at Grand Central Station at the time specified are these: Roe did not actually see the plaintiff and defendant at the Grand Central Station at the time in question, he simply heard they were there from plaintiff, Roe is a confirmed liar, Roe would not recognize the

plaintiff or the defendant if he saw them, his eyesight is very poor, Roe is related to and very friendly with the plaintiff, it was very dark at the time and place in question and Roe could not have seen these men, plaintiff and defendant were very friendly both before and after this occurrence, defendant did not own a weapon, Roe was convicted of numerous crimes including perjury, Roe is very susceptible to suggestion, Roe's statement is improbable in numerous particulars, he had innumerable talks about the matter with plaintiff and his lawyer, that Roe made previous contradictory statements and that he is biased and prejudiced against people like the defendant.

Any or all of these facts would tend to create doubt or disbelief in the proposition being maintained by the plaintiff. The list of unfavorable facts set forth here could be expanded almost ad infinitum.

This illustration should make the distinction between the two varieties of unfavorable facts more apparent. Facts of variety number one (those that support the cross-examiner's contentions) are not intended to impugn or impeach the credit or trustworthiness of the story or the witness. Factual examples of variety number one in this supposititous case are: the plaintiff and defendant were very friendly before and after the time when the shooting is supposed to have occurred and that the defendant never owned a weapon. These two facts do not impeach Roe's trustworthiness or contradict Roe's statement that plaintiff and defendant were at the Grand Central Station at the time specified. These two facts merely lend support to the cross-examiner's contention that the shooting did not occur, on the theory that it is improbable that the defendant shot plaintiff if they were so friendly both before and after the occurrence was supposed to have taken place, and if the defendant never owned a weapon. The search for facts of the second variety is made to induce disbelief, or to destroy confidence or trust in the story or the witness or both.

The art and the skill in conducting an actual cross-examination consists in knowing when to question a witness and in knowing what to extract from each witness and how to do it.

To cross-examine or not to cross-examine, that is the first question. Cross-examination is a double edged sword. It is a dangerous weapon to use. Before a lawyer commences to question each witness, he wonders, "What hidden facts will the cross-examination reveal? Will these hidden facts strengthen or weaken the case of the cross-examiner?

Will they show that the witness is trustworthy or unreliable? Will the cross-examiner develop facts favorable or unfavorable to the cross-examiner's case? Will the answer give the witness a personal victory over the cross-examiner?" The lawyer faces this dilemma before every question is asked on cross-examination unless he knows in advance exactly what answer the witness will give in response to each question. What an enigma for the cross-examiner who is in doubt as to what the witness may know or say or do. "There lies the real danger in cross-examination and there begins the art."

The danger is enhanced by the fact that if a witness is strenuously cross-examined and not impeached in any particular, the story and the witness will be strengthened in the eyes of the triers of the facts, on the assumption, that a witness who is not discredited after a thorough and searching cross-examination must be telling the whole and entire truth. Though the belief is common among witnesses and juries that "a lawyer can do anything with a cross-examination," that he "may make the worse appear the better reason" and that he "may make the truth appear like falsehood," lawyers know that these ideas are wholly without basis or foundation. Cross-examination has been aptly described as a "mental duel" between lawyer and witness. This "duel" often results disastrously for the lawyer as these illustrations reveal:

An instance is furnished by a surgeon's suit for a substantial fee. "Can you tell me," asked the lawyer, "How long it took to knock off that operation?" "Two hours" replied the surgeon. "The labor of two hours then is that for which you ask $1500?" "No," replied the surgeon, "I ask it for the knowledge of a lifetime." The lawyer asked one question too many in this exchange with a renowned surgeon, and came off second best.

A well known illustration, reported by Wigmore, concerns the famous Lord Coleridge in the case involving a Sister of Mercy, who was expelled for transgression of the rules of the Convent, and therefore commenced suit for libel. Coleridge contended that the breaches of discipline were trivial. He pressed Mrs. Kennedy, "the matron," on the point, asking what had Mrs. Saurin done? Mrs. Kennedy said as an example that she had eaten strawberries. "Eating strawberries!" exclaimed Coleridge, "What harm was there in that?" "It was forbidden, sir" said Mrs. Kennedy—a very proper answer. "But Mrs. Kennedy" reiterated Coleridge "what trouble was likely to come from eating

strawberries?" "Well, sir," replied Mrs. Kennedy, "You might ask what trouble was likely to come from eating apples, yet we know that trouble did come from it." The answer floored Coleridge.

Though art of cross-examination begins with knowing when "to cross-examine or not to cross-examine," it centers around knowing what to extract from each witness so that the direct examiner's case may be weakened, and his witnesses and their testimony discredited, and in knowing how to extract it. So that physicians may more successfully cope with an effective cross-examination, the methods employed by cross-examiners to achieve these ends are for convenience and simplicity being arbitrarily divided into four categories: (1) The vulnerable points of the case; (2) Material for cross-examination; (3) Fixed objectives and (4) The manner of questioning the witnesses.

1. The cross-examiner constantly hunts for the vulnerable spots in the story and the witness—those vital spots that seem most susceptible to a successful attack. The skillful cross-examiner develops a sixth sense in discovering the vulnerable points in each case. The vulnerable points in a given case may be its most improbable feature or a particular trait or characteristic of a witness. The facts in each case, and the make-up of each witness, determine the points of vulnerability in the matter. The physician's records, or the fees said to have been received, or the nature of the treatments administered may reveal angles that will serve as targets for investigation. Similarly, features affecting the witness himself may lead to the place where the attack should be directed—examples of these would be: The witness's memory or his opportunity to observe what he claims he saw or the witness's temper or stubbornness or bias or relationship to a litigant. There is really no limit to the possible number of vulnerable spots that can be selected.

2. While the direct examination unfolds, and while the cross-examination is in progress, the cross-examiner searches for material for cross-examination—the ammunition that the cross-examiner uses for attacking the witness. Whereas the vulnerable spot is the target, the material for the cross-examination is the weapon with which the attack is made. The finest ammunition is a statement, or a writing, that contradicts or is inconsistent with a witness's oral testimony. The search for material really commences long before the trial. The search is made for everything and anything that might

affect the witness's credit or contentions.

3. An effective cross-examination demands that counsel have definite and fixed objectives in mind while the cross-examination is in progress. However, wherever possible, the cross-examiner keeps these objectives hidden from the witness. It is axiomatic that "the only way to get anywhere is to know where you are going." This is especially appropriate advice for cross-examination. These fixed objectives may be broad or narrow. To discredit a witness or a story may be the mission of the cross-examination or it might consist in being to secure an admission from the witness that he "does not remember what happened on November 30, 1939 at 3 A.M. at Grand Central Station." Each unfavorable fact that counsel might elect to extract can constitute a separate fixed objective for the cross-examiner. To explore generally into a particular subject matter could likewise be an objective. Any end might serve as an objective for the cross-examiner.

4. It is the answer rather than the question that weakens the case or impeaches a witness. It is the answer that either affirms or denies the unfavorable facts that the cross-examiner seeks to extract. The cross-examiner's problem is to persuade the witness to give or to obtain from him the desired answer. The questions are simply the means by which these objectives are attained. Since witnesses do not always easily or willingly disclose the answer that is wanted, a plan of attack (a method of questioning each witness) will be devised that is best calculated to achieve the desired end. The technique of questioning witnesses actually utilized in law courts is based on sound and tested principles of logic, psychology and human nature.

The method of questioning witnesses naturally varies a great deal. The cross-examiner sometimes adopts a rapid fire method of questioning. This is tried to prevent a witness from manufacturing a story as the examination proceeds. The rapidity of questions may force the witness to answer truthfully because he is not given time to create a cohesive fabrication. The psychology of suggestion is another device of the cross-examiner. Here the form of the question is intended to suggest an answer. With a pliable witness, the question may be phrased so as to suggest the desired answer. With a hostile or stubborn witness the question may be so phrased that

the desired answer is wholly contradictory to what the witness thinks the cross-examiner wants. Being a contrary-minded person, or an individual who does not want to be led, this witness will disagree with what he thinks the cross-examiner wants—irrespective of whether it is true—on the theory that an answer opposite from what the cross-examiner apparently seeks must be good for the side this witness favors. What may be called the "off-guard technique" is often used with success. There a witness will be asked a series of questions on an apparently immaterial problem, and then a pertinent question will be shot at the witness on the subject about which the cross-examiner is most anxious for information. The witness may be off guard and thus give a truthful reply. With a malingering faker claiming deafness, the cross-examiner may ask the witness as he leaves the stand—when the witness is less alert, believing that the examination is concluded and in a voice too low to be heard by the witness if his claim of defective hearing were true—"Mr. Jones, didn't you forget this piece of paper?" If the witness hears the question, he will probably give an answer. It must be apparent that illustrations of this character could be set forth without limit. Those given are merely intended to give the reader a sketchy idea as to what is meant by the "ways of questioning" a witness.

Though each witness and each case is an individual problem for the cross-examiner, for decades similarities were discerned by experienced cross-examiners both in witnesses and in the factual situations as to which witnesses were questioned. Experience taught the trial lawyer that with witnesses of a similar kind, or with a like factual situation, a reasonably effective cross-examination could be conducted along substantially similar lines. Substantially identical cross-examinations—here called standard patterns of cross-examination—thus developed, and these standard patterns were passed down by lawyers from generation to generation. So long as they worked satisfactorily they were used. When "existing" patterns cease to be effective, lawyers will develop new ones. Where similar witnesses or factual situations occur frequently, the cross-examination for that character of witness or situation becomes quite standardized and routine. The lawyers themselves do not always realize when a given examination is a "standard pattern of cross-examination." Unfortunately and all too frequently, the cross-examiner's "stock in trade" consists of a few "standard patterns" and when these are ex-

hausted without advantage to the cross-examiner, the lawyer feels more beaten than the witness.

Based on these similarities, witnesses and factual situations are classified, typed and catalogued for cross-examination. There are various types and kinds of witnesses, the exaggerator, the child and the expert and the like. Substantial similarities will exist for each of these separate types. The variety of different factual situations is equally numerous. There would be included here the automobile accident, the execution of a will, the making of a contract and any kind of factual situation involved in litigation. Each of these factual situations will have certain things in common. Nothing appearing here is intended to convey the impression that standard patterns of cross-examination are tricks. They are nothing of the kind. The "standard patterns" are sound legitimate methods of cross-examination based on tried and tested principles. No case is ever concluded without some examples of standard patterns of cross-examination. This article will consider those patterns of cross-examination that will confront the physician most frequently.

"Never cross-examine an expert in his own field" is an oft repeated adage. This advice is earnestly followed by skillful lawyers in the examination of physicians. Lawyers thus avoid a cross-examination of the purely medical aspects of the physician's testimony, unless the character of the litigation makes it essential for the lawyer to study and acquaint himself thoroughly with such phases of the case. Physicians must anticipate, therefore, that generally, they will be cross-examined concerning non-medical matters.

Before illustrating standard patterns of cross-examination with typical appropriate examples, a word of general advice to witnesses with respect to the art of answering questions might be in order. Though this advice may appear too obvious, it is amazing how infrequently it is followed. The witness should listen to each and every question carefully and he should think over the question before hazarding an answer. The witness may and should take all the time that may be reasonably necessary to give an answer. No extra points are scored for speed. If the witness does not understand a question he should say so and request that it be repeated. If the meaning of the words are not clear, he should ask for enlightenment. It is better to be known as an ignoramus than a liar. If the witness does not know, or remember the answer, he should say so. If he is not sure or certain of the answer, he should reply that

he believes, or thinks, that the correct answer is so and so, but that he is not sure or certain of it. However, the solution for this, is not for the witness to answer that he does not know or does not remember when he does in fact know, or does in fact remember, for this is a false answer. If a witness was asked, "Did you ever serve a term in Sing Sing prison," the answer "I do not remember" would hardly satisfy.

The witness should answer the specific question asked. This may seem like unnecessary advice but it really is quite important. Each answer should be responsive to the question. If the witness gives an unresponsive answer the jury may believe that he is deliberately attempting to be evasive. Volunteering information not called for may be quite dangerous, and it may serve to give the cross-examiner ammunition to discredit the witness. Many famous cases illustrate how the habit of answering only the question asked, and of avoiding the practice of volunteering information not called for in the question proved extremely helpful to the side that called the witness. A classic illustration of this principle is reported by Reed on "Conduct of Law Suits":

> "Some time ago the writer, while waiting in court, watched the trial of a case where the plaintiff sought to recover damages for a breach of warranty. The defendant had sold him a horse with an express warranty that he was sound and kind and free from all 'outs.' The next day the plaintiff noticed that a shoe was loose, and he undertook to drive him into a blacksmith's shop to have him shod, when the horse exhibited such violent reluctance that he was obliged to abandon the attempt. Repeated efforts made it evident that he never would be shod willingly, and therefore he was obliged to sell him. The defendant called two witnesses. The first, an honest, clean looking man, testified that he was a blacksmith, that he knew the horse in question perfectly well, and he had shod him about the time referred to in the plaintiff's testimony. 'Did you have any difficulty in shoeing him?' asked the defendant's counsel. 'Not the least. He stood perfectly quiet. Never had a horse stand quieter.' The other, a venerable-looking man, with a clear, blue eye, testified that he had owned the horse and that he was perfectly kind. 'Did you ever have any trouble about getting him into a blacksmith's shop?' 'Well, sir, I don't remember that I ever had occasion to carry him to a blacksmith's shop while I owned him.'
>
> "The plaintiff's counsel evidently thought that the cross-examin-

ation would only develop this unpleasant testimony more strongly, so he let the witnesses go. The jury found for the defendant. The next morning, as the writer was sitting in court waiting for a verdict, a man behind him, whom he recognized as the blacksmith, leaned forward and said, 'You heard that horse case tried yesterday, didn't you? Well, that fellow who tried the case for the plaintiff didn't know how to cross-examine worth a cent. I told him that the horse stood perfectly quiet while I shod him; and so he did. I didn't tell him that I had to hold him by the nose with a pair of pincers to make him stand. The old man said he never took him to a blacksmith's shop while he had him. No more he did. He had to take him out into an open lot and cast him before he could shoe him.'"

Witnesses should remember that it is not essential to impress the jury that they possess a high I.Q. They should convey the impression that they are honest, fair and trustworthy. This is especially so where the witness is being asked to testify as to facts. Where the witness is called upon to express an opinion, or to act as an expert, the learning, the qualifications and the experience of the witness then become quite relevant.

A few examples of "standard patterns" of cross-examination follow:

1. An investigation as to a physician's qualifications and experience is a "standard pattern" of inquiry. The investigation will ordinarily cover the physician's hospital connections, the phases of medicine in which he specializes, the number of cases similar to the case in suit that he has previously handled, his experience in the field of medicine under inquiry, his familiarity with the medical writings on the subject and all those factors from which a doctor's qualifications and experience are usually measured. The physician's answers should be frank and fair and his qualifications should not be exaggerated or minimized. The witness stand is not the place for self-praise or self-derogation. Each can be ruinous for the physician. An example of what happened to a physician who tried to appear more learned than he actually was is set forth at this point. It involved a suit for disability insurance benefits. Plaintiff claimed total disability as a result of a heart condition—angina pectoris. The insurance company's physician was a heart specialist. Counsel for the plaintiff came to the conclusion that the defendant's physician was inclined to exaggerate; that he was unwilling to admit ignorance on any subject affecting heart disorders. The witness gave the impression of being an unusually pompous individual. Plaintiff's counsel thereupon

prepared a list of texts which included two fictitious works. "Harrison on Heart Disease" and "Page on Heart Failure," which were "manufactured" by counsel. The pertinent cross-examination relative to the medical authorities follows:

Q. Are you familiar with the authoritative texts on heart disease?
A. Of course.
Q. I suppose that you have read the authoritative texts and refer to them constantly in your work, correct?
A. I would say that I possess most of them in my own library.
Q. Have you heard of Lewis on Diseases of the Heart?
A. Certainly.
Q. Have you heard of Levine on Clinical Heart Disease?
A. Of course.
Q. These books are standard authorities on the heart?
A. That is correct.
Q. I suppose that there are few books on the heart that are not known to you?
A. I would say that is correct.
Q. Have you heard of P. D. White on Heart Disease and Harrison on Heart Disease?
A. I have.
Q. What about Page on Heart Failure and Anderson on Heart Diseases?
A. Certainly.
Q. Would you say that you have read or examined all the books that I have mentioned?
A. I would say that I not only read them but studied them carefully as well.
Q. Do you know whether any of the books that I have mentioned contain statements contrary to the conclusions that you have made?
A. I do not recall, though I doubt it. If they exist, show the passages to me. You apparently have a number of medical text books on the counsel table.
Q. Do you keep abreast of all current writings on the heart?
A. That's essential in my specialty.
Q. How frequently would you say that you have had occasion to study or refer to the texts that I have mentioned?

A. I refer to them constantly in my practice.

Q. How recently have you done this with respect to the six texts that I have mentioned?

A. My practice compels me to do this constantly, it deals exclusively with the heart.

Q. How many standard texts on the heart do you find it necessary to refer to constantly?

A. That is a foolish question. I refer to the standard texts that you mentioned.

Q. Doctor, I show you this catalogue of medical books and ask you if it is not a fact that Harrison on Heart Disease and Page on Heart Failure, which you stated are standard texts, and which you constantly refer to and study in the course of your practice, are not fictitious and non-existent?

A. No answer.

This physician's trustworthiness and credit were certainly impaired. The impeachment of this witness could have resulted from a conscious design to deceive or from wholly innocent causes. All people, to a degree, are susceptible to the power of suggestion. All persons have had the experience, while conversing with a friend, of being asked "Why you remember David Dantos from back home" and they reply "Oh, of course," or "I think I do," when they don't recall the fellow at all. The witness stand is not the place to be accommodating or careless. It is during cross-examination that the witness must be especially alert and awake and scrutinize and consider each question before answering.

Courts and juries do not expect experts to know everything, and it is unwise for physicians to attempt to give this impression. No person need feel disgraced if he is compelled to say "I do not know," or "I do not remember."

2. A cross-examination concerning doctors' medical records is a very common subject of inquiry. An example of such an examination follows:

Q. Doctor, will you please let me see the medical records to which you referred on direct examination?

A. Shall I, Judge?

Court: Yes, doctor, since you used the records on direct examination, counsel has a right to examine them.

The physician hands the records to counsel who then proceeds to

examine them. The cross-examiner hunts for vulnerable spots in the records and searches them for material for cross-examination.

Q. Did you ever know or see this patient or treat him before this case?

A. Never before.

Q. Are these records in your handwriting?

A. Yes, they are.

Q. Now, doctor, weren't these records written up recently and all at one time?

A. Yes, they were. You are 100 per cent correct there. I wrote them up yesterday. I made this copy from my original records because of this court case.

Q. In what respect do your original records differ from or contradict these records?

A. They are identical.

Q. Are they on the same form of card?

A. Exactly the same.

Q. Have you the original records with you?

A. No, I didn't think I needed them and thus did not bring them with me.

Q. Where are the original records now?

A. At my office.

Q. And where is that?

A. ..... Park Avenue, Manhattan.

Q. Why did you bring the copy with you instead of the original?

A. They are both identical. I felt it would suffice.

Q. It is now 2:30 P.M.—how long would it take you to get the original records and return with them.

A. I haven't got the time to do that.

Q. If my clerk should leave with you now, would it be possible for you to return to your office and give my clerk these original records?

A. I can't waste all day on this case.

Counsel: I ask your Honor to direct Dr. ..... to pick up his original records and to return with them to court this afternoon.

(Colloquy between counsel and the court).

Court: Doctor, since the request for your original records

is made, I must ask you to get them and produce them. You will be excused for this purpose.

Witness: Frankly, your Honor, I do not think I could find them. I made these records yesterday intending to bring the original records to court, to leave the original records with the court if it desired them and to retain the copy as my permanent record. I placed the copy in my metal index file and put the original in my wallet pocket. This morning, I looked for the original records and could not find them. I searched for a half hour without success. They must be in my office or at home, somewhere. I suppose I should have admitted this before. I have never lost records before and felt quite embarrassed about it. I should not have tried to bluff my way out of it.

Q. When you tried to bluff your way out of it you knew you were under oath?

A. Yes, I did.

Q. When you stated that you did not bring the original records with you because you did not think you needed them, that was false and untrue, wasn't it, doctor?

A. Well, I suppose it wasn't true but I did feel that the copy would satisfy you.

Q. You originally intended to bring the original to court?

A. Yes, I did.

Q. So you testified falsely when you stated that you did not bring the original record because you did not think you would need it, is that not correct?

A. My answer was untrue.

When a witness takes the stand he swears that he will tell the truth, the whole truth and nothing but the truth. The cross-examiner hopes to catch the witness in a lie on the theory that if the witness lies in one respect the court and jury will believe that he is careless about the truth and that he is the lying kind. Bluff is not recommended. Physicians should always bring their original records to court. To produce copies will only create the impression that the originals are non-existent. This advice should be followed even if the copy is in a more convenient form. If the doctor desires to produce both original and copy, and leave the copy, should the court require it, this can be done. It is a mistake to leave the original at the doctor's home, or office.

A cross-examination as to a physician's records is so frequent an inquiry that a second example is being given. An effective cross-examination in this field is illustrated by a case involving a possibly fractured skull. The physician testified to these injuries: a deep laceration on the hand, a period of unconsciousness (ten minutes), bleeding from the nose and ears, nausea and headache. These are what the physician found on the first visit. X-rays of the skull were taken in various positions. The pictures were negative. The doctor's diagnosis was a fractured skull. The doctor kept the patient in bed for three weeks.

After the doctor's records were turned over to counsel, the cross-examination proceeded in this manner:

Q. Notwithstandnig the x-ray you persist in your diagnosis of a fractured skull?

A. Yes, a fracture of the base of the skull. The x-ray is not conclusive. To me the findings are more impressive.

Q. Without what signs and conditions would you not have made a diagnosis of fractured skull?

A. All the things I found are important. I am not sure that I quite follow you.

Q. If the plaintiff had not suffered from headaches and nausea when you first examined him, would you have made a diagnosis of fractured skull?

A. He was suffering from these and told me so.

Q. I repeat, if you did not find the plaintiff suffering from headache and nausea, you would not have made that diagnosis, is that correct?

A. Without nausea, I still may have, in view of the other findings, without head pains, no.

Q. Without bleeding from the nose and ears, would you have made that diagnosis?

A. Without bleeding from the nose, yes. Without bleeding from the ears, no.

Q. If there was no bleeding from the ears you could not have made a diagnosis of fractured skull in this case.

A. That is absolutely correct.

A series of questions were then asked the doctor to divert his attention from the subject of bleeding from the ears.

Q. Have you an independent recollection of what you saw the

plaintiff suffering from and what he told you, or is this case just like a thousand others and do you only remember what the patient had because of your records?

A. I remember this case very well.

Q. Do you remember asking your patient questions and summarizing on this card what you were told and what you found?

A. I put down what was important.

Q. You remember doing that in this case?

A. Yes.

Counsel now picks up the card, and while looking at it, asks these questions:

Q. You were told that the injuries resulted from falling plaster and you made a record as to that, correct?

A. Correct.

Q. Falling plaster could have caused a bloody nose?

A. There was no mark on the nose.

Q. You do not say there was no mark on the nose in this record, doctor?

A. Where there is no mark or injury to a part, I make no record as to that. I made no entry that there were no marks or injuries to the man's legs or toes, either.

Q. Since you knew this injury would result in a lawsuit, you were especially careful in the making of records, were you not?

A. I was primarily concerned with curing the patient, not winning a lawsuit.

Q. You knew there might be a lawsuit?

A. I did not think about it.

Q. You made a record of how the injuries occurred and all the injuries that you found and observed?

A. I always do that, accident or no accident.

Q. And you did that in this case?

A. I did.

Counsel continues to examine card as he questions the witness.

Q. You were told about headaches and you put that down?

A. Correct.

Q. Plaintiff told you about nausea and you put that down?

A. That's right.

Q. You saw a deep laceration on the skull and you recorded that

on this card?

A. I put down everything I saw that was important.

Q. You saw bleeding from the ears and you made a note as to that on this card?

A. I did.

Q. Doctor, you have an independent recollection of writing down all these things?

A. Of course.

Q. Do you recall whether you wrote the entry regarding the bleeding from the ears, with pen or pencil?

A. Pen.

Q. With what color ink?

A. I always use green ink.

Q. Your memory as to all this is clear enough so that you can see yourself doing all this?

A. Of course.

Q. And what plaintiff didn't suffer from you did not write down?

A. I have told you this before.

Q. Doctor, isn't it a fact that there is no entry whatsoever on this card regarding bleeding from the ears?

A. No answer.

The physician's records serve as a very fruitful beginning for a successful cross-examination. A written record is more eloquent and convincing than a thousand spoken words. The solution for a cross-examination as to records is more careful and thorough records, and a searching scrutiny of these records by doctor and counsel before the doctor takes the stand. There is no excuse for a physician being surprised as to the contents of his own records.

3. Physicians should anticipate a cross-examination as to hypothetical questions covered during the direct examination. In almost every case wherein a physician testifies, a hypothetical question is asked. Bouvier's Law Dictionary defines a hypothetical question as "a question put to an expert witness containing a recital of facts assumed to have been proved, or proof of which is offered in the case and requiring the opinion of the witness thereon." The standard pattern of cross-examination, with reference to such question is to proceed in either of two ways (1) to induce the expert to admit that a few specific facts among the many assumed facts in the question are the "sine qua non" or essen-

tial facts of the opinion without which the conclusion would not be possible, and then to attack the existence or non-existence of those essential facts, and (2) to ascertain how the opinion of the expert would be affected by adding to the hypothetical question new facts not originally contained in the question.

As an example a case is set forth here wherein the physician claimed that on an assumed state of facts it was his opinion that the decedent was insane. The assumed facts were as follows: decedent suffered from periods of excitement and depression; he refused to see four of his five children; he believed in spiritualism; he felt that four of his children were extremely anxious for him to die; he was very irritable and obstinate; he complained of constant headaches and these existed for about three years prior to the time decedent died, at the age of sixty-nine years; and he suffered from frequent and violent spells of intoxication and fits of temper. A few of the questions asked the expert follow:

Q. Would you say that everybody who believed in spiritualism was insane?

A. No.

Q. Would you say that a belief in spiritualism in and of itself is an evidence of insanity?

A. Not in and of itself, but I think it is an evidence of insanity in this case.

Q. Was the decedent's belief in spiritualism peculiar or different from the ordinary variety of spiritualism, and if so, describe in what way it differed?

A. I know of no way in which decedent's belief differed from general beliefs on the subject.

Q. Then is it correct that it is the decedent's belief plus the other facts assumed by you that convinced you that decedent's belief in spiritualism is important?

A. Yes.

Q. We agree, therefore, do we not, that a belief in spiritualism in and of itself is no evidence of insanity?

A. I would agree with you there.

Q. And the decedent's belief in spiritualism alone and in and of itself is no evidence of insanity, is that correct?

A. I would say so.

The same series of questions were then directed to all the assumed

facts in the hypothetical question. Counsel finally persuaded the expert to admit that three facts were sufficient by themselves to convince the doctor that decedent was insane, to wit, the fact that decedent believed that four of his children were anxious to have him die, that he refused to see four of his children, and that he suffered from periods of excitement and depression. The examination then proceeded in this way:

Q. Would you say that each of these three factors independently suffice to justify a conclusion decedent was insane, or would you say that the combination of these three factors compel that conclusion?

A. The combination.

Q. So that if any of these three factors did not exist you would say that there was an insufficient basis to form an opinion that the decedent was not sane?

A. Excepting if the decedent had practically continuous periods of excitement and depression without let-ups and without any periods of normalcy I might say that that alone was sufficient.

Q. However, you know that the hypothetical question did not assume any such state of facts?

A. Yes, that is true.

Q. And you know that there is no claim that the decedent suffered from practically continuous periods of excitement and depression and that the testimony is to the contrary, do you not?

A. Yes, so I have been told.

Q. So it is correct, is it not, that you believe that it is a combination of these three factors that brings you to the conclusion?

A. I suppose so.

Q. And that if any of these three factors did not exist you personally would not or could not come to the conclusion that decedent was insane?

A. I think that is so.

Q. If you should assume that before decedent refused to see four of his children, those children constantly demanded of decedent whenever they were with him that he divide his wealth among his children before he died, and whenever he would see these four children there were constant arguments and bickering concerning that subject with a result that decedent would become terribly ill and excited—would you say that his refusal to see

those four children was without cause or reason?

A. That would depend on just how violent the arguments and the bickering were.

Q. You do not consider it an evidence of insanity do you, if a man of sixty-eight years of age refuses to divide his wealth among his children, do you?

A. No.

Q. If four of decedent's children constantly harped on the subject, do you believe that a sane man might become aggravated and would find it unpleasant to see his children?

A. Those facts were not asked me when I rendered my opinion.

Q. Well, I ask you to assume those facts and ask you whether or not that would alter your opinion?

A. I would say that it probably would.

Q. If the children had expressed sentiments to various people that if the father would only die his wealth would be distributed among them, and these facts were conveyed to decedent, would you say that the decendent's belief in this regard was an insane delusion and the idea of an insane man?

A. If that fact were established I would say that it was not unreasonable.

Q. I am asking you to assume that fact, am I not?

A. Yes.

Q. All the other facts upon which you base your conclusion were assumed and not proved, is that not correct?

A. That is true.

Q. And it is correct, therefore, is it not, that if the decedent's belief concerning his children's wish that he die and that the decedent's refusal to see these four children had a basis in fact and reason, that you would come to a different conclusion with respect to the insanity of the decedent?

A. I would be compelled to do that.

Q. If any of the three factors which you concluded were an essential basis for a conclusion of insanity did not in fact exist, you would say that the decedent was sane, is that not true?

A. I would have to.

The expert should see the hypothetical question before he takes the stand. Especially is this true if it is lengthy, for counsel for the adverse

side may ask the physician to repeat it or to repeat the facts which the physician feels are essential for the opinion. The physician should discuss the hypothetical question with counsel before the trial. He should determine and advise counsel what are the essential and the non-essential facts.

4. A cross-examination as to physician's fees or compensation is quite a frequent occurrence. In connection with a case involving personal injuries such cross-examination follows:

Q. Did you come to court today pursuant to subpoena?
A. No, I did not.
Q. You came voluntarily, merely as a result of a telephone call or an oral request?
A. Yes.
Q. You expect a fee for testifying in court today?
A. Yes, I hope that I will receive one.
Q. Do you expect to be paid?
A. Yes, I do.
Q. Have you had any conferences with counsel or with the plaintiff with respect to fees for attending court?
A. No.
Q. No fee has been fixed yet?
A. No.
Q. Who asked you to come to court?
A. Mr. Blank (counsel for plaintiff).
Q. Did you see Mr. Blank before he called you?
A. He came up to see me at my office about three weeks ago.
Q. Was the subject of fees for your appearance today broached at all?
A. No, it was not.
Q. When did Mr. Blank call you on the 'phone about coming to court?
A. Yesterday.
Q. Was the subject of fees or money for your appearance in court discussed over the 'phone by Mr. Blank?
A. No, it was not.
Q. Did you ever have a talk concerning fees for appearing in court with the plaintiff?
A. No.

Q. When Mr. Blank called you to ask you to come to court, did you say anything about being paid for coming to court?
A. No.
Q. As a result of your appearance here in court you have been unable to visit a number of patients and thus you will suffer a financial loss by testifying?
A. That is true.
Q. When you stated that you would appear in court, you knew that you would suffer a financial loss unless you were paid for this court appearance?
A. Yes.
Q. But notwithstanding that, nothing whatsoever was mentioned about your fee by you or Mr. Blank, is that correct?
A. That is true.

A physician as an expert is privileged to charge a fee for expert testimony. An ordinary witness cannot demand compensation for testifying. Physicians sometimes fear that they cannot admit that they have been paid or promised a fee for a court appearance. Knowing that it is proper to receive compensation should make it possible for the physician, who is aware of this fact, to defend himself against this standard pattern of cross-examination. Where physician's records as to fees—the charges made and the payments received and the number of house and office visits—are not accurately kept, he can expect trouble from an inquiry along these lines. The remedy is quite simple—better records. Where the physician anticipates that the case will end in court, the records should be kept with an eye toward cross-examination. Nine times out of ten the history will reveal this.

The preceding examples were given to illustrate "standard patterns of cross-examination" affecting subject matter. A "standard pattern" can relate to the field of inquiry or the manner of questioning a witness.

A cross-examination as to details is a "standard pattern of cross-examination"—it is a way of questioning a witness. It may be pursued in any field of inquiry. A cross-examination as to details is probably the most frequent method utilized by cross-examiners. The phrase "standard pattern of cross-examination as to details" is intended to describe a cross-examination concerning all the details or particulars of any situation. The inquiry will search into every nook and corner and every phase of a subject. Usually, the cross-examiner hopes by pursuing this

method to test either the memory or the trustworthiness of the witness. The theory behind a cross-examination as to details is that if a witness did not actually live through the experiences claimed to have occurred, he will not be able to consistently or cohesively manufacture or create or imagine the details as fast as the questions are asked. A cross-examination of this character is designed to develop inconsistencies, contradictions and improbabilities in the witness under examination or between that witness and others who have testified. This is a "standard pattern" that may take place in practically any field of inquiry. An examination of this variety may necessitate a long and protracted questioning before any results are achieved. If a cross-examination as to details is had as to visits and treatments (where counsel suspects that the number of visits and the extent of the injuries are exaggerated), the cross-examiner may question the physician as to these matters: what complaints were made by the patient and what treatments were administered on each visit, the exact respects in which the plaintiff's complaint and condition differed on each visit, in what respect each treatment differed from each other, exactly what entries were made on each visit covering each complaint, finding and treatment, exactly when each medicine or treatment was discontinued, when each injury healed, duration of each visit. An inquiry into all these items would be made in the most minute detail. A case illustrating a cross-examination as to details follows. These physician's records contained full particulars of the patient's first visit and they set forth the date of each subsequent visit, but there was nothing in the records regarding the patient's complaint or the doctor's findings or treatment on any visit following the initial examination. Notwithstanding this, the doctor testified in quite minute detail as to the patient's complaints and the physician's own findings and treatment on numerous occasions that he saw the patient. The patient sustained what appeared to be a pretty usual garden variety of fractured arm. The doctor saw the patient twenty (20) times. He recalled special findings, complaints and treatments prescribed on eight of these, including the first visit. After thoroughly questioning the doctor as to everything that occurred on each visit, the cross-examination took this tack:

Q. The plaintiff suffered from a simple fracture of the left arm, is that correct?

A. Yes.

Q. Are the records that you produced and exhibited to me the only records that you have regarding this case?
A. Correct.
Q. Was there anything extraordinary or unusual about this fracture and if so will you describe it?
A. No, there was not.
Q. The last visit was made two years ago, is that correct?
A. Yes.
Q. Was there anything striking or outstanding about this case that makes it stand out in your mind above all others, and if so, describe what that is?
A. No, I wouldn't say that there is.
Q. I suppose that on the average you have treated at least ten patients per day during the last two years?
A. Probably more.
Q. Have you an equally good recollection as to the cases of all your patients?
A. Yes, I have a pretty good memory.
Q. That means that you have treated on the average about sixty patients per week?
A. Yes.
Q. Since the time that you treated the plaintiff you have had occation to make at least 6,000 visits?
A. Yes, I suppose so.
Q. And can you recall the exact complaints made to you and the exact findings made by you, and the exact treatment administered by you on each of those 6,000 visits, with the same detail that you were able to recall these things with respect to the plaintiff?
A. No, I can't say that I could.
Q. Do you recall the names of any patients you saw on the same days that you saw the plaintiff?
A. No.
Q. Can you tell us what complaints were made to you or what findings were made by you, or what treatments were administered by you to any patients that you saw on the days that you saw this plaintiff?
A. No, I can't.

Q. Doctor, have you really and honestly an independent recollection as to what you were told by the plaintiff, and as to what you saw and did on each visit following the first examination, or did you tell us what is usual and customary in fractures of this kind?

A. Well, it may be that I am stating what the usual findings and treatment are for cases of this kind.

At this point more than any other, the advice concerning the statement "I don't know," and "I do not recall," bear repetition. If a witness blithely details what no human being can remember, the person will be branded as a liar.

Every subject upon which a doctor may be questioned can not be set forth in an article of this length. However, there are a few fields of inquiry and methods of examination which should be mentioned—even though they are not discussed fully—in an attempt to set forth the minimum that every physician should know about cross-examination:

1. *Medical Texts:* Prior to the trial, lawyers sometimes gather together medical texts concerning statements which support the propositions for which they are contending and which may differ from what the medical witness is likely to maintain. The physician will be confronted with these "medical authorities" on cross-examination. Before coming to the court the doctor should read up on the subject upon which the examination will be had and familiarize himself with names and authors of medical works in the field and know what books are considered authorities. This rehearsal will enable the physician to convincingly disagree with the medical texts where the statements made therein are unfounded and will enable the physician to support his contentions by books or printed authorities, which always influence court and jury.

2. *Extent of Court Work:* Lawyers will invariably ask a medical witness how much time he spends in court, how frequently he testified, whether or not he is customarily called for plaintiffs or defendants, the type of cases to which he is most often asked to appear and how often the physician has come to court for counsel in the case. The best defense to this line of inquiry is to know what is coming—and it generally does.

3. *Relationship between Physicians and Lawyer and Patient:* The

lawyer will explore into the length of time that the witness knows counsel and patient, whether the doctor forwarded the case to the lawyer, how friendly the parties are, and the like. The cross-examiner's design is to show that the doctor is not a disinterested witness and that the testimony is colored by friendship. This line of cross-examination is not as effective with the triers of the facts as counsel ordinarily believes. The advice given under the heading "*Extent of Court Work*" applies with equal force here. To be forewarned is forearmed.

4. *Subjective Symptoms:* Where the patient's injuries or principal injuries are largely subjective, the physician can expect from a competent cross-examiner a strenuous cross-examination about the matter. The cross-examination will first determine what are the subjective symptoms, what are partly subjective and what the doctor actually saw or found. The cross-examiner will endeavor to find out what exists solely in the patient's mind and what can be established by objective findings. Since cross-examination is designed to test the truth it cannot be expected that "tricks" can be taught to evade its effect. A remedy for this does exist and that is a more thorough examination of the patient by the physician and more complete and careful records. Wherever an appearance in court is a possibility, the physician should remember that he will be questioned as to what complaints and injuries are subjective symptoms.

5. "Have you talked with anybody about this case?" is a common question. Laymen "fall" for this quite frequently. Physicians only rarely. The usual pattern of this cross-examination is in this form:

Q. At any time before today did you discuss this matter, or the testimony that you have just given with any person?

A. No.

Q. Did you ever discuss this matter with the attorney who just questioned you?

A. No.

Q. You testified on direct examination that you personally witnessed the automobile accident?

A. Yes.

Q. At any time did you discuss with the attorney who questioned you the facts or details as to what you saw?

A. No.

Q. Will you please then explain to this court and jury how that

attorney knew what you were going to say, or was aware of the fact that you saw this accident?

A. No answer.

Naturally this witness will be discredited in the eyes of the tribunal. Each and every juror is fully aware of the fact that this witness did talk with the party who questioned him, or with his attorney, or with somebody. Unless he had given his name to some person and told what he knew, he would not have been called as a witness. The witness was undoubtedly of the opinion that it was wrong or improper for a witness to talk with anybody concerning the matter. It is perfectly proper for a witness to talk with any person in advance of the trial. As a matter of fact the witness should go over the matter with the attorney who calls him before he appears in court, and he should ask the attorney to cross-examine him in the same way that the witness will be cross-examined on the trial. Likewise the witness should thoroughly familiarize himself with each and every angle of the case about which the cross-examination can be anticipated, and especially regarding all the facts that may appear to be unfavorable to the side for which the witness is being called. It is not wrong to prepare oneself thoroughly for trial.

Preparation is the key to success for the medical witness. A lawyer prepares for cross-examination. Why should the physician do less in anticipation of this mental duel? The physician's preparation should commence with the examination of the patient and with the making of the medical records of the case. Both should be made with an eye toward the trial. Before the trial a study should be made of the subject matter of the pertinent texts and the authorities should be examined. Conferences with the patient and the lawyer before testifying are most desirable. If all these instructions are followed the doctor will step up to the witness stand ready to devour the blood of the cross-examiner.

SIR FREDERICK GRANT BANTING*

CHARLES H. BEST

Director, Department of Physiology and Banting and Best Department of Medical Research
University of Toronto

BANTING will always be remembered primarily for the preëminent part he played in the discovery of insulin and I feel that you will wish me to speak particularly of that phase of his brilliant career.

Banting's ancestors were of Irish and Scotch extraction. I remember a very pleasant week end spent with him and his parents at their farm house shortly after the first stage of the insulin work was completed. His mother, whose maiden name was Grant, died only a year before her son. Both she and his father were of sterling worth. I have a letter from Banting written in answer to a note of condolence at the time of his mother's death. He wrote "The death of our parents places us in the front line."

After qualifying at the High School in Alliston, where he was born, Banting entered the University of Toronto. He was the type of student whom his instructors remembered. He had an inquisitive mind. His medical course was interrupted by the Great War but after enlisting as a private, he was sent back to obtain his degree. He completed his course in 1917 and immediately entered the Army. He took a very great interest in his military patients and many of them kept in touch with him throughout his life time. The high point of his military career was his experience in France, where he won the Military Cross for bravery in action.

After the war he specialized in surgery at the Sick Children's Hospital in Toronto, where he gained the friendship of such men as the late Professor C. L. Starr, Professor W. E. Gallie and Dr. D. E. Roberston. When Banting left the Sick Children's Hospital he began the practice of medicine in London, Ontario. The growth of his practice was disappointingly slow and Banting spent some time demonstrating in the Department of Physiology of the University of Western Ontario. While preparing a lecture on diabetes, he read an article by Dr. Moses Barron.

* Read October 2, 1941 at the Stated Meeting of The New York Academy of Medicine.

Banting always felt that Dr. Barron, whom I think he subsequently met, had helped him to form an hypothesis which was in part responsible for the initiation of the work which led to the isolation of insulin.

Banting went to Toronto in the autumn of 1920 to consult Professor J. J. R. Macleod who was recognized as one of the world's greatest authorities on carbohydrate metabolism. I was spending part of my time that year in physiological research under Macleod's direction but I did not meet Banting until the next spring just after I had completed my course in Physiological and Biochemical Sciences. Macleod told me about Banting's desire to search for the internal secretion of the pancreas and he spoke admiringly of Banting's determination. This quality was the outstanding one in his character and was immediately apparent when I met him in May, 1921, a few days before the investigations which resulted in the isolation of insulin were begun. The initiation of the work was due entirely to him and he overcame all of the many obstacles in his path.

It will perhaps serve as a further appreciation of his character if I outline a few of the incidents which seemed to us important at the time. When the first five weeks of work revealed the fact that our technique for securing pancreatic degeneration was unsatisfactory, Banting did not hesitate to finance himself for a further period by selling his small car. He sometimes performed minor operations for some of his medical colleagues. He loaned me a small sum which was only repaid when Professor Macleod in the autumn made arrangements for us each to receive the sum of $60 monthly. My payments and, I think, Banting's were dated back for several months.

Banting was a skilful and resourceful surgeon. For the first few months all of the chemical work fell to my lot but he gradually learned the techniques and he taught me the surgical procedures essential to our work. There were, of course, many problems but our association during those busy months gave me a tremendous respect for his perseverence and peculiar ability to plan attacks and to carry through the investigation. We became very firm friends. His letters to me and the charts and illustrations for our first articles which we worked on together, are among my most prized possessions. I will always be indebted to him for his generous references to my part in the insulin investigations, for sharing equally with me his half of the Nobel Prize award and for his numerous demonstrations of thoughtfulness and regard. At the last com-

mittee meeting which we attended together, a few weeks before his death, an extension of my department was under consideration by members of our Board of Governors. Banting's unselfish and most helpful interest in this matter is recorded in the minutes of that meeting.

Our very intimate association in research, which began on May 16, 1922, persisted until October 1923, when I decided to proceed with my medical course. Shortly after that the Banting and Best Department of Medical Research was created and Banting was installed as Director. He worked very hard at numerous problems over the period of sixteen years until the present war was upon us. He devoted himself mainly to cancer research but found time to stimulate many young associates who attacked a great variety of problems. The work on silicosis was perhaps the most successful.

I firmly believe that his second great contribution was made in the eighteen months of war when he sacrificed all his personal interests and gave himself unsparingly to organizing our country for research in the various aspects of war medicine. He devoted himself primarily to the medical aspects of aviation and eventually, as you all know, gave his life while attempting to carry new information on these problems to England.

Banting was a man of exceptional physical courage, intense determination, and warm friendships. He achieved the distinction of becoming our most illustrious Canadian citizen. He will be commemorated in many ways but he would have asked nothing more than that every attempt be made to extend and apply the results of the work which he began.

RECENT ACCESSIONS TO THE LIBRARY

"Possession does not imply approval"

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PROCEEDINGS OF ACADEMY MEETINGS

STATED MEETING

MAY 21—*The Harvey Society (in affiliation with The New York Academy of Medicine).* The Eighth Harvey Lecture, "The Comparative Anatomy and Pharmacology of the Pituitary Body," Eugene M. K. Geiling, Professor of Pharmacology, University of Chicago Medical School. Report on election of Academy Fellows.

SECTION MEETINGS

MAY 1—*Surgery.* ¶ Executive session—a] Reading of the minutes; b] Election of Section Officers and member of Advisory Committee: for chairman—Frank J. McGowan, for secretary—John V. Bohrer, For member of Advisory Committee—Frank B. Berry. ¶ Presentation of cases—a] 1. Tuberculosis of the appendix, 2. Friedländer's bacillus pneumonia with secondary lung abscess. Operation—Recovery, D. Rees Jensen; b] Cases of diabetic gangrene. Healing under conservative therapy (lantern slides), Saul S. Samuels. ¶ Paper of the evening—The topical use of sulfanilamide and sulfadiazine in various media in the treatment of burns, Adrian V. S. Lambert. ¶ General discussion.

MAY 5—*Dermatology and Syphilology.* ¶ Presentation of cases—a] Beth Israel Hospital; b] Brooklyn Jewish Hospital; c] Cornell University Medical College. ¶ Discussion. ¶ Executive session—Election of Section Officers and member of Advisory Committee: for chairman—Frank C. Combes, for secretary—Samuel M. Peck, for member of Advisory Committee—Eugene F. Traub.

MAY 5—*Combined Meeting: Neurology and Psychiatry and the New York Neurological Society.* Reading of the minutes. ¶ Papers of the evening—a] The electroencephalogram in epilepsy, Francis A. Echlin, discussion by Paul Hoefer, Margaret Rheinberger, Ph. D. (by invitation); b] A psychopathological review of senile and arteriosclerotic disorders, Oskar Diethelm (by invitation), discussion by John H. Travis; c] Mental cachexia: Nature and management, John L. Smalldon (by invitation), discussion by Leland E. Hinsie, Howard W. Potter. ¶ Executive session of the Section—Election of Section Officers and member of the Advisory Committee: for chairman—Charles Davison, for secretary—Gerald R. Jameison, for member of the Advisory Committee—George H. Hyslop.

MAY 13—*Historical and Cultural Medicine.* ¶ Executive session—a] Reading of the minutes; b] Election of Section Officers and member of Advisory Committee: for chairman—Herman Goodman, for secretary—Edward F. Hartung, for member of Advisory Committee—Claude E. Heaton. ¶ Paper of the evening—Hand and occupation: A study in the history of occupational medicine, George Rosen (by invitation), discussion by Leonard Greenburg, Louis Tulipan. ¶ General discussion.

MAY 14—*Pediatrics.* ¶ Executive session—a] Reading of the minutes; b] Election of Section Officers and member of Advisory Committee: for chairman—Charles Hendee Smith, for secretary—Edith M. Lincoln, for member of Advisory Committee—Alfred G. Langmann. ¶ Presentation of single case reports—a] Babies Hospital, refractory rickets, Donovan J. McCune (by invitation), Beridge Robertson (by invitation); b] Beth Israel Hospital, Edema with unexplained hypoproteinemia, lipemia and eosinophilia, Jean Wolfson (by invitation); c] Bronx Hospital, hepatic necrosis, Henry Weisman (by invitation); d] Lenox Hill Hospital, Subdural hematoma, Julian L. Rogatz; e] Mount Sinai Hospital, Trichobezoar of

the stomach, Philip J. Kresky (by invitation); f] New York Hospital, A rare congenital anomaly of the lung, Samuel W. Dooley (by invitation); g] New York Post-Graduate Hospital, Pseudohermaphroditism in a case of adrenal hyperplasia, Vincent de P. Parkin (by invitation); h] Roosevelt Hospital, Hypoglycemia convulsions with subtotal pancreatectomy, Agnes G. Wilson (by invitation), Howard A. Patterson; i] New York Infirmary for Women and Children, Primary tuberculosis of the conjunctiva, Margaret Sedam (by invitation), Olga Sitchevska (by invitation); j] Beth Moses Hospital, Glycogen storage disease with cardiomegaly, Harry Wexler, Abraham R. Kantrowitz; k] Bellevue Hospital, Multiple osteomyelitis of the new born, Samuel Stone (by invitation); l] Willard Parker Hospital, Asthma with pulmonary tuberculosis and compression of the vagus nerve, Nicholas F. Fiegoli (by invitation), Theodore Ehrenreich (by invitation).

MAY 15—*Orthopedic Surgery.* ¶ Executive session—a] Reading of the minutes; b] Election of Section Officers and member of Advisory Committee: for chairman—John C. McCauley, Jr., for secretary—Halford Hallock, for member of Advisory Committee—Joseph Buchman. ¶ Papers of the evening—a] Paget's disease—a new theory of etiology and its relationship to vitamin C, Frederick R. Thompson, discussion by Mather Cleveland, David M. Bosworth, and Samuel Kleinberg; b] A new approach to the diagnosis of herniation of intervertebral discs, William R. Duncan (by invitation), discussion by Lewis Clark Wagner and Kenneth M. Lewis; c] Tuberculosis of the greater trochanter and adjacent bursae, Joseph B. L'Episcopo, Edward Haggerty (by invitation) and David M. Bosworth; d] Osteitis pubis—report of a case in a woman, Samuel Kleinberg.

MAY 18—*Ophthalmology.* ¶ Instruction hour: 7:00 to 8:00 o'clock—a] Binocular ophthalmoscopy and red-free light in fundus diagnosis—Ralph I. Lloyd; b] Clinical meeting; ¶ Executive session: 8:30 o'clock—a] Reading of the minutes; b] Election of Section Officers and member of Advisory Committee: for chairman—Daniel B. Kirby, for secretary—Richard T. Paton, for member of Advisory Committee—Kaufman Schlivek. In memoriam — Henry Robertson Skeel, W. Guernsey Frey. ¶ Presentation of cases —a] A case of congenital anterior synechiae, corneal opacities and microphthalmos, Frederick H. Theodore; b] A case of tumor of the optic nerve, William B. Agan (by invitation); c] Cases of congenital absence of lacrimal puncti. Three cases in the same family, Arno E. Town (by invitation); d] A case of reconstruction of the lower eyelid—Bernard Fread; e] A case of thrombosis of the central vein treated with heparin, Charles M. Rosenthal (by invitation); f] A case of modification of Wheeler's tasorrhaphy—Daniel B. Kirby; g] A case of congenital prepapillary cyst, Jesse M. Levitt (by invitation); h] A case of bilateral pigmentation of the retina with macular changes, Gerald T. Schwarz (by invitation); i] A case of epithelioma of the cornea, George N. Wise (by invitation).

MAY 19—*Medicine.*—¶ Executive session—a] Reading of the minutes; b] Election of Section Officers and member of Advisory Committee: for chairman — Irving S. Wright, for secretary—Martin Henry Dawson, For member of Advisory Committee—Asa L. Lincoln. ¶ Papers of the evening—a] The metabolism of the human sperm in relation to survival and fertility (with moving picture demonstration), John McLeod (by invitation); c] Discussion by Ephraim Shorr (by invitation).

Genito-Urinary Surgery. The following were elected at the April meeting of the Section: chairman—Frank P. Twinem, secretary—John H. Rathbone, member of Advisory Committee—John H. Morrissey. No meeting of the Section was

held due to the meeting of the American Urological Association in New York, June 1-4.

MAY 20—*Otolaryngology.* ¶ Executive session—a] Reading of the minutes; b] Election of Section Officers and member of Advisory Committee: for chairman—John Winston Fowlkes, for secretary—Victor Carl McCuaig, for member of Advisory Committee — Page Northington. ¶ Papers of the evening—a] Technique of planigraphy of the larynx, Murray M. Friedman (by invitation); b] The mechanism of phonation from the viewpoint of planigraphy of the larynx, Bruno L. Griesman (by invitation); c] Discussion, John D. Kernan. ¶ Case reports—a] Petrositis; paralysis of the 6th and 7th nerves; meningitis, pneumococcus Type III, Thomas G. Tickle; b] Horner's syndrome with chronic purulent otitis media: demonstration of diagnostic test, Louis Hubert; c] Laryngectomy for extrinsic cancer, Mervin C. Myerson.

MAY 26—*Obstetrics and Gynecology.* ¶ Executive session—a] Reading of the minutes; b] Election of Section Officers and member of Advisory Committee: for chairman—William T. Kennedy, for secretary — Locke L. Mackenzie, for member of Advisory Committee—Harry Aranow. ¶ Papers of the evening—a] A simple safe maneuver for the delivery of shoulders, Charles Edwin Woods (by invitation); b] The termination of pregnancy in patients with toxemia, Irving A. Bunkin (by invitation), Jefferson J. Vorzimer (by invitation), Edwin G. Langrock; c] Value of the endometrial biopsy as compared with the vaginal smear, Locke L. Mackenzie, Theodore Neustaedter, discussion by George Papanicolaou (by invitation). ¶ General discussion.

AFFILIATED SOCIETIES

MAY 18—*New York Roentgen Society (in affiliation with The New York Academy of Medicine).* ¶ Symposium of cancer of the breast—a] Autopsy findings, Angelo M. Sala (by invitation), Elma Barany (by invitation); b] Indications for radical mastectomy, Cushman D. Haagensen (by invitation), Arthur Purdy Stout (by invitation); c] Roentgen therapy of the primary tumor and axillary metastases—inoperable and preoperative cases, Maurice Lenz; d] Roentgen therapy of distant metastases, Jacob R. Freid and Henry Goldberg (by invitation). ¶ Discussion by Hugh Auchincloss (by invitation), William C. White (by invitation), William Harris and Haig Kossabach. ¶ Executive session.

MAY 28—*New York Pathological Society (in affiliation with The New York Academy of Medicine).* ¶ Presentation of cases—a] Periarteritis nodosa in scarlet fever, Vera B. Dolgopol, S. Spector (by invitation); b] Myocardial lesions in myasthenia gravis, Antonio Rottino, Robert Poppiti (by invitation). ¶ Papers of the evening—a] The origin of colloid in lipoid droplets in the epithelial cells of the renal tubules, Hans Smetana; b] Morphogenesis and significance of verrucal endocardosis (so-called terminal endocarditis or non-bacterial thrombotic endocarditis), Arthur C. Allen, Jonas M. Sirota (by invitation) ¶ Executive session.

DEATHS OF FELLOWS

BUCKLEY, ROBERT EMMETT: 50 East 63 Street, New York City; born in Connecticut in 1888; died in New York City, July 25, 1942; graduated in medicine from Yale University School of Medicine in 1911; elected a Fellow of the Academy January 3, 1929.

Dr. Buckley was director of surgery in otolaryngology to the Manhattan Eye, Ear and Throat Hospital and consulting otolaryngologist to the Misericordia and Roosevelt Hospitals. He was a Fellow of the American Medical Association, a diplomate of the American Board of Otolaryngology, a member of the American Academy of Ophthalmology and Otolaryngology, the American Laryngological Association, the American Laryngological, Rhinological and Otological Society, and the State and County Medical Societies.

CHAPIN, HENRY DWIGHT: Bronxville, New York; born in Steubenville, Ohio, February 4, 1857; died in Bronxville, June 27, 1942; received from Princeton University the degree of B.Sc. in 1877 and M.A. in 1886; graduated in medicine from the College of Physicians and Surgeons in 1881; elected a Fellow of the Academy February 4, 1886.

Dr. Chapin was emeritus professor of pediatrics at the New York Post-Graduate Medical School, Columbia University; one of the founders and on the staff of the Children's Welfare Federation; a member of the American Pediatric Society, a Fellow of the American Medical Association, and a member of the State and County Medical Societies.

HELLER, ISAAC MORRIS: 115 East 61 Street, New York City; born in New Haven, Connecticut, May 20, 1872; died in New York City, June 7, 1942; graduated in medicine from Yale University School of Medicine in 1896; elected a Fellow of the Academy January 6, 1910.

Dr. Heller was a member of the medical board and attending otolaryngologist to the Lebanon Hospital, a major in the medical branch of the Officers Reserve Corps, a Fellow of the American College of Surgeons, a Fellow of the American Medical Association, a diplomate of the American Board of Otolaryngology, a member of the American Laryngological, Rhinological and Otological Society and a member of the State and County Medical Societies.

1942 GRADUATE FORTNIGHT

OCTOBER 12 TO 23

"DISORDERS OF THE NERVOUS SYSTEM"

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EVENING LECTURES

The subjects and speakers at the evening lectures will include:

Pathology of head injuries.....Timothy Leary
Principles of treatment of closed head injuries.....D. Denny-Brown
Principles of treatment of penetrating and perforating wounds of the brain.William Cone
Subdural hematoma (and other late results of head injury).....E. Jefferson Browder
Military Psychiatry.....Edward A. Strecker
The emotions and disease.....Harold G. Wolff
Tidal drainage and cystometry in the treatment of the bladder in the presence of spinal cord injuries.....Donald Munro
Diagnosis and treatment of brain abscess.....Joseph E. J. King
Differential diagnosis and prognosis of brain tumors.....Gilbert Horrax
Certain abnormalities of ocular movements: their importance in general and neurologic diagnosis.....Frank B. Walsh
Wounds and injuries of the spinal cord.....Byron P. Stookey
Surgical treatment of pain.....Francis C. Grant
Treatment of speech disorders.....Stanley Cobb
Multiple sclerosis and "encephalomyelitis'.....Tracy J. Putnam
Limitations of vitamins in neurology.....Charles D. Aring
Present status of shock therapy.....Nolan D. C. Lewis
Prefrontal lobotomy.....Walter Freeman
Types of psychotherapy and indications for them.....Lawrence S. Kubie
Migraine and other forms of headache.....Henry A. Riley
Epilepsy and its treatment.....William G. Lennox

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